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The form relations of the lead oxychlorides, laurionite, paralaurionite, and fiedlerite.

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THE published data on these three minerals, first found in the Laurion lead slags, is well summarized in Hintze (Handb. Min., 1915, vol. 1, pp. 2632–2641). In studying the original papers for the purpose of recalculating the elements of each, LaForge was impressed with their close crystallographic relationship in certain respects and with the curious complexity of the form series of fiedlerite, which seemed to call for further observations. Accordingly, crystals of all three minerals from Laurion were studied on the goniometer, specimens loaned by the U.S. National Museum furnishing a welcome supplement to those found in the Harvard Mineralogical Museum. In the following pages the results of these studies will first be presented in brief form. Following this, the conclusion arrived at as to the most appropriate positions of the three minerals to bring out their mutual relationships will be stated.

[1] The author desires to acknowledge his indebtedness to his co-workers in this study. Dr. L. LaForge made the preliminary studies and calculated some of the tables. Dr. M. A. Peacock made some of the measurements and all of the drawings. Mr. H. Berman determined the optical properties of all three of the minerals.

Fig. 1 shows the relations of the angles given in the angle-tables:

$A = (hkl) : a\,(100)$; $B = (hkl) : b\,(010)$: $C = (hkl) : c\,(001)$.

$\phi\ \rho$: co-ordinate angles in normal position.

$\phi''\ \rho''$: ,, ,, ,, second inversion.

In the orthorhombic system $c(001)$ lies at the pole and $\rho = C$; in both the orthorhombic and monoclinic systems $\rho'' = B$.

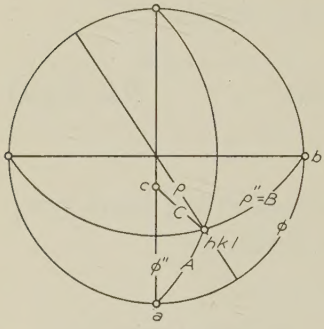

Fig. 1. Angular relations in the monoclinic system.

Laurionite—$PbCl_2.Pb(OH)_2$, orthorhombic.

LaForge computed the elements of laurionite from the measurements of Koechlin (1887), vom Rath (1887), Smith (1899), de Schulten (1897), Cesàro (1904), and Russell (1928), and obtained the values in the first line of table 1. Palache and Peacock measured ten crystals of laurionite on the two-circle goniometer and from the observations made on sixty faces of five forms (table 2) calculated the elements in the second line. Combining this new set of values (weighted as one) with those resulting from older measurements (weighted as four), the final values were obtained. These elements, transformed to the new position described below, were made the basis of the new table of calculated angles (table 3).

Table 1. *Laurionite. Elements.*

	a : *b* : *c*.	p_0.	q_0.
LaForge (computed) ...	0·7331 : 1 : 0·8304	1·1327	0·8304
Palache & Peacock ...	0·7354 : 1 : 0·8302	1·1288	0·8302
Weighted mean ...	0·7336 : 1 : 0·8304	1·1320	0·8304

Table 2. *Laurionite. Two-circle measurements on ten crystals.*

(Position and symbols of Koechlin.)

Form.		Number of faces.	Number of crystals.	Palache, measured ϕ''.	Palache, measured ρ''.	LaForge, calculated from earlier observations ϕ''.	LaForge, calculated from earlier observations ρ''.	Calculated from new elements ϕ''.	Calculated from new elements ρ''.
m(*k*)	(110)	21	8	53° 45′	90° 0′	53° 45½′	90° 0′	53° 44½′	90° 0′
n	(120)	15	6	34 18	,,	34 17½	,,	34 16½	,,
d	(012)	8	6	0 0	22 40	0 0	22 33	0 0	22 33
q	(122)	9	4	34 21	45 6	34 17½	45 9	34 16½	45 8½
r	(132)	9	3	24 27½	53 44	24 27	53 50½	24 26	53 50

TABLE 3. *Laurionite. Angle-table.*

$a : b : c = 2{\cdot}4084 : 1 : 1{\cdot}7668.$

$p_o = c/a = 0{\cdot}7336, \quad q_o = c = 1{\cdot}7668.$

Form.	ϕ.	$\rho = C$.	ϕ''.	$\rho'' = B$.	A.
c(001)	—	0° 0′	90° 0′	90° 0′	90° 0′
a(100)	90° 0′	90 0	0 0	,,	0 0
d(110)	22 33	,,	,,	22 33	67 27
e(310)	51 14½	,,	,,	51 14½	38 45½
l(102)	90 0	20 8½	69 51½	90 0	69 51½
k(101)	,,	36 15½	53 44½	,,	53 44½
h(302)	,,	47 44	42 16	,,	42 16
n(201)	,,	55 43½	34 16½	,,	34 16½
o(111)	22 33	62 24	53 44½	35 4	70 8
u(312)	51 14½	54 40½	42 16	59 17	50 29½
q(211)	39 42½	66 28	34 16½	45 8½	54 9
r(311)	51 14½	70 29½	24 26	53 50	42 41½
p(812)	73 14½	71 55½	18 49	74 5½	24 27
s(411)	58 57	73 43½	,,	60 19	34 40½
t(511)	64 16½	76 12	15 15	65 4½	28 58

(hkl) (Palache) = $(l.h.2k)$ (Koechlin).

The dominant habit of laurionite crystals is tabular parallel to a pinacoid taken by most observers as (010) and elongated in the direction of the vertical axis. Ktenas (1910) was the first to suggest a different orientation in which the dominant pinacoid is taken as (100) and the direction of elongation as the b-axis. This orientation is adopted in the present paper, and the following description is in terms of that position. The crystals are of three habits:

(1) Thin rectangular tables with dominant macropinacoid a, the edges of the tables truncated by narrow faces of the prism d and the macrodome k (fig. 2). Rectangular striations on a are due to oscillatory combination with p or some vicinal form near it (fig. 3).

(2) Thicker tabular crystals with the pinacoids a, c (narrow or missing), the macrodomes k and n, the prism d, and one or more of the pyramids o, q, r, s, t forming a diagonal striated zone (figs. 4 and 5). The form u was also found on a crystal of this type and the new form e(310), but these are not figured.

(3) Tabular or lath-shaped crystals with a, c, and k, the end spear-shaped, due to the development of p without the prism or with the point of the spear truncated by d (figs. 5 and 6). The form here indicated as p (812) is really a group of vicinal forms with large and brilliant faces which vary in position through a range of several degrees both in ϕ and ρ. They have been recorded by several observers and have been assigned symbols such as (812), (922), and (511) in our

notation. A large number of observations are shown in fig. 8 plotted in gnomonic projection. The plot shows that the symbol (812) expresses the simple rational position to which most of the observa-

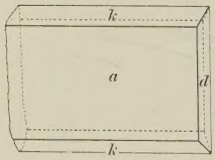

Fig. 2.

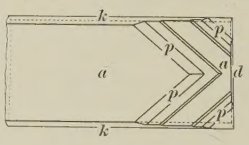

Fig. 3.

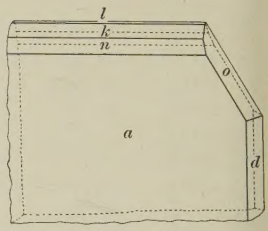

Fig. 4.

Crystals of laurionite.

tions were nearest. All considerations point, however, to vicinal development. Table 4 correlates the observations of various authors on laurionite.

Table 4. *Laurionite. Forms and symbols according to various authors.*

	vom Rath 1887.	Koechlin 1887.	Smith 1899.	Cesàro 1904.	de Schulten 1897 (artificial).	Palache 1934.
c(001)	*b*(010)	*a*(100)	*a*	h^1	—	*c*
a(100)	*a*(100)	*b*(010)	*b*	g^1	—	*a*
d(110)	*d*(108)	*d*(012)	*d*	e^2	*d*	*d*
*e(310)	—	—	—	—	—	*e*
l(102)	*l*(190)	*l*(210)	—	—	—	*l*
k(101)	*n*(290)	*m*(110)	*m*	*m*	*m*	*k*
h(302)	—	—	—	h^5(320)	—	—
n(201)	*m*(490)	*n*(120)	*n*	g^3	*n*	*n*
o(111)	—	—	*o*(112)	—	—	—
u(312)	—	—	*u*(232)	—	—	—
q(211)	—	—	*q*(122)	—	—	*q*
r(311)	—	—	*r*(132)	—	—	*r*
p(812)	*o*(111)	—	*p*(141)	(141)	—	*p*
s(411)	—	—	*s*(142)	—	—	*s*
t(511)	—	—	*t*(152)	—	—	—
Uncertain Forms.						
(104)	—	(410) ?	—	—	—	—
(203)	—	(320) ?	—	—	—	—
(403)	—	(340) ?	—	—	—	—
(601)	—	(160) ?	—	—	—	—
(912)	—	—	—	(292)	—	?
(10.1.2)	—	*p*(151)	(151)	—	—	?

* New form.

The cleavage of laurionite has been variously described. Vom Rath stated that it was parallel to b(010), which in our position is (001), with which Dana (System, 1892, p. 171) agrees. Cesàro gives

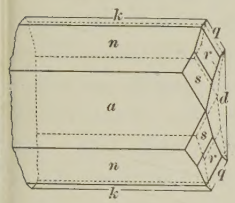

Fig. 5.

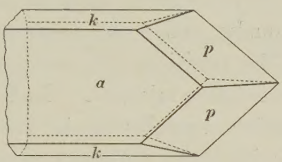

Fig. 6.

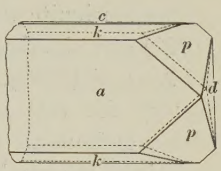

Fig. 7.

Crystals of laurionite.

the cleavage parallel to his m(110). This we found to be correct, and in the new orientation this becomes the macrodome k(101). Although the pinacoid a(100) has a pearly lustre which suggests cleavage in that direction, none could be discovered. Cesàro states that the plates are easily bent about the direction of the brachyaxis. Of this character, so prominent in paralaurionite, we were unable to find a trace. It seems likely that Cesàro mistook a crystal of paralaurionite for laurionite, which is very easily done.

The optical properties of laurionite were re-determined by Mr. Berman, whose observations are in essential agreement with those of Smith. Berman found by immersion in melts:

$$\alpha\, 2{\cdot}08,\ \gamma\, 2.16\ (\pm 0{\cdot}01).$$

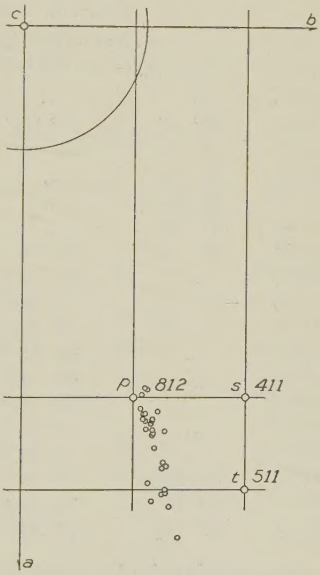

Fig. 8. Laurionite. Gnomonic projection of vicinal forms observed on seven crystals: interpreted as constituting the form p(812).

In the new orientation: $a = c$, normal to cleavage cracks; $\beta = a$, normal to dominant pinacoid; $\gamma = b$, parallel to elongation. 2V is large and probably negative. The plane of the optic axes is parallel to a (100). Consequently, no optical figure can be obtained on the

ordinary crystals which are tabular parallel to a, in contrast to paralaurionite whose plates exhibit a characteristic optical figure.

PARALAURIONITE—$PbCl_2.Pb(OH)_2$, monoclinic.

Paralaurionite was first described from Laurion by G. F. H. Smith (1899) and simultaneously, under the name of rafaelite from Chile, by Arzruni (1899). The position and elements of Smith are satisfactory for this monoclinic mineral. LaForge has recalculated elements from all published angles of the observers named and has combined the results with those obtained from the measurements of five crystals from Laurion made in the present study. The resulting elements, practically the same as those derived by Smith, are the basis for computation of the angle-table shown below.

TABLE 5. *Paralaurionite. Angle-table.*

$a : b : c = 2{\cdot}7042 : 1 : 1{\cdot}8090$, $\beta = 62° 47\frac{1}{2}'$.

$p_o = c/a = 0{\cdot}6687$, $q_o = c \sin \beta = 1{\cdot}6088$.

Form.	ϕ.	ρ.	C.	B.	A.
c(001)	90° 0′	27° 12½′	0° 0′	90° 0′	62° 47½′
b(010)	0 0	90 0	90 0	0 0	90 0
a(100)	90 0	,,	62 47½	90 0	0 0
m(110)	22 34½	,,	79 53½	22 34½	67 25½
n(310)	51 16½	,,	69 6	51 16½	38 43½
e(201)	90 0	63 38½	36 25½	90 0	26 21½
f(401)	,,	74 9	46 56½	,,	15 51
g($\bar{2}$03)	−90 0	0 44½	26 28½	,,	99 15½
d($\bar{1}$01)	,,	13 22½	40 35	,,	103 22½
h($\bar{2}$01)	,,	44 42	71 55	,,	134 42
k($\bar{4}$01)	,,	68 9	95 21½	,,	158 9
i($\bar{5}$01)	,,	72 52½	100 5	,,	162 52½
l($\bar{6}$01)	,,	75 57½	103 10	,,	165 57½
j($\bar{8}$01)	,,	79 42	106 54½	,,	169 42
p(111)	34 59½	65 38	52 43	41 43½	58 30½
y(411)	62 49	75 49½	52 15½	63 42½	30 24½
t(511)	67 3½	77 50½	53 12	67 36	25 48½

The paralaurionite crystals measured in our study yielded several new forms which have been included in table 5. The forms and average observed angles are shown in table 6 (p. 579).

The close agreement between measured and calculated angles is noteworthy. The crystals of this mineral are of an unusual degree of perfection. The habit of paralaurionite is markedly tabular, the broad plates being either rectangular, as in fig. 9, or wedge-shaped owing to the development of pyramid faces at the corners of the plates, as in figs. 10 and 11.

Twinning on (100) is wellnigh universal, the symmetrical contact-twins having full orthorhombic pseudosymmetry. Re-entrant angles between the two members were rarely observed. The twin crystals are generally simple contact-twins as shown in figs. 9, 10, 11, and in fig. 12, a more complex crystal. Figs. 13 and 14 illustrate beautifully symmetrical interpenetration-twins on the same law; they recall the type of twin crystal of albite from Roc Tourné in Savoy, figured

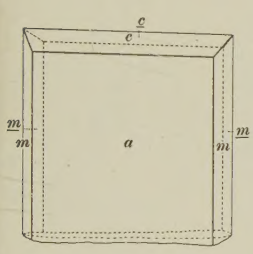

Fig. 9.

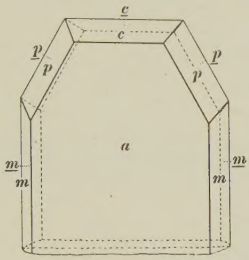

Fig. 10.

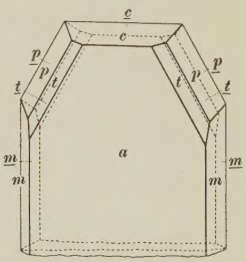

Fig. 11.

Symmetrical contact-twins of paralaurionite.

Table 6. *Paralaurionite. Measured and calculated angles.*

Form.	Number of faces.	Measured ϕ.	Measured ρ.	Calculated ϕ.	Calculated ρ.
c(001)	7	90° 0′	27° 15½′	90° 0′	27° 12½′
a(100)	10	,,	90 0	,,	90 0
m(110)	10	22 34	,,	22 34½	,,
h($\bar{2}$01)	5	−90 0	44 37	−90 0	44 42
k(4̄01)	3	,,	68 12	,,	68 9
*i(5̄01)	1	,,	72 35	,,	72 52½
l(6̄01)	2	,,	75 56	,,	75 57½
*j(8̄01)	1	,,	79 20	,,	79 42
p(111)	10	35 1	65 40	34 59½	65 38
*t(511)	4	67 0	77 50	67 3½	77 50½

* New forms.

by G. Rose (Dana, System, 1892, p. 329, figs. 10, 11). The resemblance extends to the grooves on the pinacoid which are in these crystals bounded by faces of steep orthodomes. The cleavage is parallel to the base (001), and in the twins the two cleavages simulate closely the macrodome cleavage of laurionite save that the inclination of the cleavage to the vertical is less, 27° 15½′ in paralaurionite, 36° 15½′ in laurionite. The broad pinacoidal plates of paralaurionite bend so easily parallel to the b-axis that it is difficult to detach crystals from the matrix without distortion. The plates

break easily into slender ribbons parallel to b, the edges showing a fibrous silky cleavage surface much like the $(\bar{1}11)$ cleavage of gypsum.

The optical properties of paralaurionite were studied by Mr. Berman

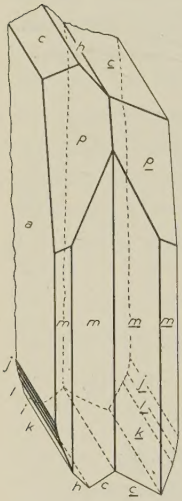

Fig. 12.

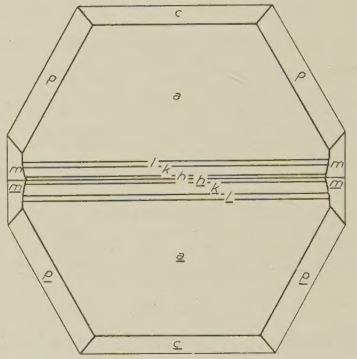

Fig. 13.

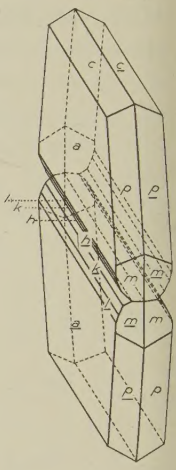

Fig. 14.

Twinned crystals of paralaurionite.

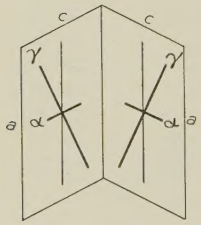

Fig. 15. Optical orientation of twinned paralaurionite.

with the aid of the Fedorov stage (fig. 15). On (100) the twin plates show a highly diagnostic abnormal interference-figure due to twinning. The optical axial plane is parallel to (010) and the extinction is 25° to the twin-plane (100), in the obtuse angle β; $\beta = b$, $\gamma : c = +25°$. Biaxial negative, 2V medium to large, $r < v$ strong.

α 2·05, β 2·15, γ 2·20 ($\pm$0·01).

The indices were obtained in melt immersions; the heat required for immersion produced a slight alteration in the substance revealed by a change of colour from white to light yellow. That this change is not a large one is indicated by the close agreement of the value found for β with that (2·146) measured by Smith without heating. There was also slight alteration in birefraction and axial angle after immersion in the melt.

FIEDLERITE—$2PbCl_2.Pb(OH)_2$, monoclinic.

Fiedlerite was first described from Laurion by vom Rath (1887) and again by Smith (1899). The complex indices of the forms reported by both observers invited a re-examination of the crystallography. This was made possible by the study of crystals found on a specimen from the Roebling collection, kindly loaned by the United States National Museum. Fiedlerite is generally tabular

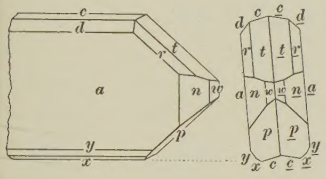

FIG. 16.

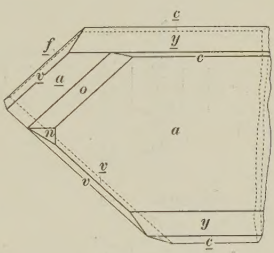

FIG. 17.

FIG. 18.

Crystals of fiedlerite.

parallel to (100) and elongated in the direction of the symmetry-axis. Five crystals were measured, their habit making it convenient to mount them on the two-circle goniometer with the orthodome zone as a prism-zone and the (missing) clinopinacoid as pole (second inversion). The measured and calculated angles are therefore given in that position (table 7).

Most of the crystals are twins on (100) as shown in figs. 16 and 17. One simple crystal, however, while its faces were not of the best, yielded new forms which permitted the choice of a new unit pyramid and a satisfactory simplification of the form series. This crystal, a left-hand end, is shown in fig. 18, projected on $(0\bar{1}0)$.

From the data of table 7 elements were calculated as follows:

$a : b : c = 1{\cdot}0121 : 1 : 0{\cdot}8996$, $\beta = 77° 39'$.

Second inversion $p_o'' = 1{\cdot}1386$, $q_o'' = 1{\cdot}0121$.

Normal position $p_o = 0{\cdot}8888$, $q_o = 0{\cdot}8783$.

A graphical comparison of these elements with those employed by vom Rath and Smith showed that with our choice of units the symbols are considerably simplified. It proved that the equivalence of the elements could be expressed by the following transformations:

$\frac{5}{4}a$ (vom Rath) $= \frac{5}{4}a$ (Smith) $= a$ (Palache)

c „ $= \frac{5}{4}c$ „ $= c$ „

TABLE 7. *Fiedlerite. Measurements on five crystals.*

Form.	Number of faces.	Quality.	Measured Mean ϕ''.	Measured Mean ρ''.	Range ϕ''.	Range ρ''.	Calculated ϕ''.	Calculated ρ''.
c(001)	6	poor	77° 33½′	90° 0′	76° 43′—78° 19′	——	77° 30′	90° 0′
a(100)	8	very good	0 1	,,	0 0 — 0 6	——	0 0	,,
*w(110)	4	good	0 1	45 25	0 0 — 0 3	44° 30′—45° 56′	,,	45 0
m(540)	1	poor	0 0	51 2	——	——	,,	51 20
n(320)	2	,,	0 2	55 55	0 0 — 0 4	55 50 —56 0	,,	56 18⅓
*g(015)	1	fair	76 37	79 35	——	——	77 30	80 2½
*f(011)	1	,,	78 8	48 40	——	——	,,	48 43
d(101)	1	good	42 0	90 0	——	——	41 44⅓	90 0
x($\bar{1}$01)	1	poor	−55 43	,,	——	——	−55 53	,,
y($\bar{2}$01)	2	good	−32 30	,,	−32 23 —32 36	——	−32 23	,,
*r(111)	4	poor	41 31½	59 2	41 16 —41 57	58 45 —59 18	41 44½	59 5½
e(144)	5	good	66 13	50 40	64 42 —68 13	49 57 —51 2	65 56½	50 36½
*t(122)	3	fair	55 39	53 17	55 0 —56 19	53 12 —53 22	56 7½	53 15½
*s(342)	1	good	32 25	45 47	——	——	32 29½	45 59½
p($\bar{1}$22)	3	,,	−75 14½	49 0	−74 32 —76 40	48 52 —49 8	−77 10	48 45
*v($\bar{3}$44)	2	poor	−65 52	50 44	−65 48 —65 56	50 33 —50 55	−65 39	50 40½

* New forms.

Transforming the elements of each observer accordingly and averaging the values with our own with equal weights we obtain:

vom Rath	... $a=0{\cdot}8192$	$\frac{5}{4}a=1{\cdot}0240$	—	$c=0{\cdot}8915$	$\beta=77°\ 20'$
Smith	... $a=0{\cdot}8299$	$\frac{5}{4}a=1{\cdot}0372$	$c=0{\cdot}7253$	$\frac{5}{4}c=0{\cdot}9066$	$\beta=77\ 31$
Palache	... —	$a=1{\cdot}0121$	—	$c=0{\cdot}8996$	$\beta=77\ 39$
	Mean (adopted)	$a=1{\cdot}0244$		$c=0{\cdot}8992$	$\beta=77\ 30$
		$p_o=0{\cdot}8778$		$q_o=0{\cdot}8779$	

Table 8 is calculated from these mean elements.

TABLE 8. *Fiedlerite. Angle-table.*

$a:b:c=1{\cdot}0244:1:0{\cdot}8992$, $\beta=77°\ 30'$.
$p_o=c/a=0{\cdot}8778$, $q_o=c\sin\beta=0{\cdot}8779$.

Form.	ϕ.	ρ.	ϕ''.	$\rho''=B$.	C.	A.
$c(001)$	90° 0′	12° 30′	77° 30′	90° 0′	0° 0′	77° 30′
$a(100)$	,,	90 0	0 0	,,	77 30	0 0
$l(140)$	14 2	,,	,,	14 2	86 59½	75 58
$w(110)$	45 0	,,	,,	45 0	81 12	45 0
$m(540)$	51 20	,,	,,	51 20	80 16	38 40
$n(320)$	56 18½	,,	,,	56 18½	79 37½	33 41½
$g(015)$	50 57½	15 56	77 30	80 2½	9 57½	77 41½
$f(011)$	13 51	42 48	,,	48 43	41 17	80 38½
$d(101)$	90 0	48 15½	41 44½	90 0	35 45½	41 44½
$x(\bar{1}01)$	−90 0	34 7	−55 53	,,	46 37	−55 53
$y(\bar{2}01)$	,,	57 37	−32 23	,,	70 7	−32 23
$r(111)$	51 15½	55 10	41 44½	59 5½	45 47½	50 11½
$e(144)$	26 24½	45 7	65 56½	50 36½	40 47	71 38
$t(122)$	36 44½	48 17½	56 7½	53 15½	41 44	63 28½
$o(544)$	56 15	58 17½	36 37	61 47½	48 13	44 59
$u(322)$	60 12½	61 4½	32 29½	64 13	50 27½	40 34½
$s(342)$	41 7½	67 16½	,,	45 59½	59 22½	52 39
$p(\bar{1}22)$	−14 13	42 51	−77 10	48 45½	47 11	−80 23
$v(\bar{3}44)$	−26 43	45 11½	−65 39	50 40½	51 23	−71 24

For the symbols of forms in the three positions the following transformations serve:

vom Rath.	Smith.	Palache.
(hkl)	$(5h.5k.4l)$	$(5h.4k.4l)$
$(4h.4k.5l)$	(hkl)	$(5h.4h.5l)$
$(4h.5k.5l)$	$(4h.5k.4l)$	(hkl)

The crystals of fiedlerite are poor and the angles for any given form show considerable variation as all observers have remarked. With the adoption of the new elements on which the angle-table is based the form series is clarified as may be seen from table 9 in which the forms and symbols of each observer are compared.

The reason for changing vom Rath's symbols is that the new symbols are required by the transformation determined by his unit $o(111)$. In all cases, but that of u, calculation showed that the angles corresponding to the symbols obtained by transformation are as close to the measured angles as those given by vom Rath's symbols. We have no explanation for the lack of agreement in the case of u.

TABLE 9. *Fiedlerite. Correlation of forms.*

	vom Rath.	Smith.	Palache.
c	(001)	(001)	(001)
a	(100)	(100)	(100)
l	—	(150)*	(140)‡
w	—	—	(110)
m	(110)	(110)	(540)
n	(650)	(650)	(320)
g	—	—	(015)
f	—	—	(011)
d	—	(101)	(101)
x	($\bar{4}05$)†	($\bar{1}01$)	($\bar{1}01$)
y	($\bar{8}05$)†	($\bar{2}01$)	($\bar{2}01$)
r	—	—	(111)
e	(155)†	(154)	(144)
t	—	—	(122)
o	(111)	(554)	(544)‡
u	(655)†	(654)	(322)‡
s	—	—	(342)
p	($\bar{2}55$)†	($\bar{2}54$)	($\bar{1}22$)
v	—	—	($\bar{3}44$)

* Observed by Lacroix (1908).

† These symbols differ from those given by vom Rath as follows:

$x(\bar{4}05)$	vom Rath ($\bar{5}06$)	$u(655)$	vom Rath (544)
$y(\bar{8}05)$	,, ($\bar{5}03$)	$p(\bar{2}55)$	,, ($\bar{5}.12.12$)
$e(155)$	,, (5.24.24)		

‡ Not observed by Palache.

Fiedlerite has a good cleavage parallel to (100) which is also the twin-plane and the dominant crystal-form. Twins are the rule in our crystals. The optical properties were determined by Mr. Berman, using the universal stage and immersion melts (fig. 19).

$\gamma = b$, $\beta : c = -34° \pm 1°$ in the acute angle β.

α 1·98, β 2·04, γ 2·10 ($\pm$0·01).

Biaxial negative. 2V large. $r < v$ perceptible.

Due to twinning most of the crystals fail to show complete extinction on (100).

Gnomonic projections of the three minerals under consideration are shown drawn to the same scale in figs. 20, 21, and 22. Fiedlerite, which has a composition different from the other two, is distinct from them in elements and forms series. Laurionite, orthorhombic, and paralaurionite, monoclinic, show many points of similarity, the homeomorphism being better expressed by the new choice of position and elements of laurionite. Both are tabular parallel to a (100). The cleavage, k (101) in laurionite and c (001) in paralaurionite, is similar in attitude. The prism-zone of each exhibits the same

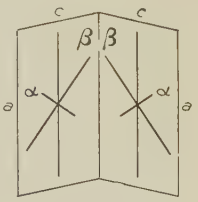

Fig. 19. Optical orientation of twinned fiedlerite.

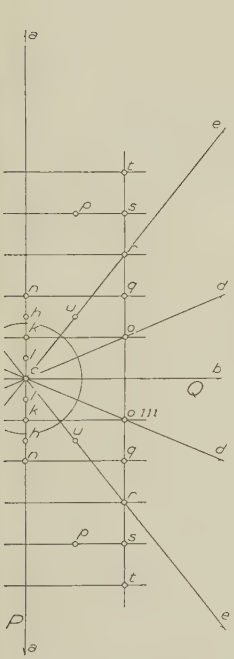

Fig. 20.

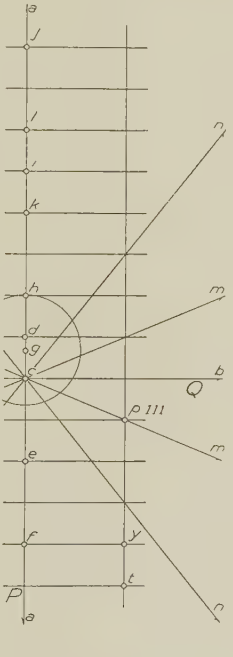

Fig. 21.

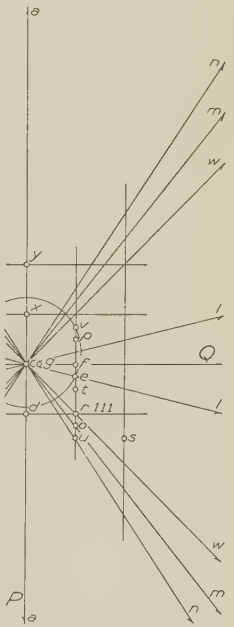

Fig. 22.

Gnomonic projections of the confirmed forms of laurionite (fig. 20), paralaurionite (fig. 21), and fiedlerite (fig. 22).

forms, both are chiefly developed in two zones, domal and pyramidal; and the spacing of the poles in both the P and Q directions is nearly the same.

Laurionite ... $p_o = 0{\cdot}7336$, $q_o = 1{\cdot}7668$.
Paralaurionite ... $p_o' = 0{\cdot}7520$, $q_o' = 1{\cdot}8090$.

The resemblance of the projections is increased greatly when we have a twin of paralaurionite on $a(100)$ with perfect orthorhombic pseudosymmetry. Nevertheless the contention of Ktenas that the two minerals are identical, the orthorhombic symmetry of laurionite being due to 'molecular' twinning of monoclinic individuals of paralaurionite, finds no support in observation. No evidence of twinning is visible in laurionite; the cleavage and optical properties are entirely distinct; and the position angles of the forms are consistently, although slightly different. The dimorphism of laurionite and paralaurionite is clearly established.

Summary.—New observations on laurionite, paralaurionite, and fiedlerite are presented. The separate identity of each of the first two minerals is confirmed and their homeomorphism is exhibited by a reorientation of laurionite. The form series of fiedlerite has been simplified by the choice of a new unit form. New forms are described on all three minerals. The crystallography of all three species is summarized in new angle-tables and their habits are illustrated by a series of drawings.

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The crystal-structure and optical properties of matlockite (PbFCl).

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With a chemical analysis by M. H. Hey, M.A., B.Sc.
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[Read June 7, 1934.]

IT has recently been shown by W. Nieuwenkamp (1) that matlockite is identical in chemical composition and crystal-structure with artificial lead fluochloride PbFCl. His conclusion is based upon powder photographs of the two substances and a fluorine determination of a specimen of matlockite from Matlock, Derbyshire. The present work was undertaken primarily to check Nieuwenkamp's interesting results. Access to an exceptionally fine suite of matlockite specimens in the British Museum collection made possible single crystal X-ray measurements, accurate optical determinations, and a new chemical analysis.

The first description of matlockite was given by R. P. Greg (2) who recognized a new mineral distinct from phosgenite on specimens of decomposed galena from 'one of the air-shafts of an old level near Cromford' (3), about a mile and a half south of Matlock, Derbyshire. Greg attributed the discovery to Mr. Bryce M. Wright of Liverpool, a mineral dealer who was also successful in collecting a few good specimens of the new mineral from old heaps of the mine at Cromford. The British Museum collection includes some of Wright's original material, and also part of the specimen which Greg passed on to Dr. Robert Angus Smith for chemical analysis. Other specimens acquired at later dates (including two from the Arkwright and Rutland mines,[1] respectively) all come from the Matlock district.

[1] Probably identical with the Rutland Cave mine, Derbyshire, a well-known locality for aurichalcite.

Four chief types of matlockite can be recognized:

(1) Single crystals mostly square, tabular, transparent and colourless or yellow to pale amber, varying in size up to an inch square and nearly a quarter of an inch thick.

(2) Flat aggregates of platy crystals in sub-parallel growth rarely quite colourless and generally translucent to opaque.

(3) Hemispherical, rosette-like aggregates of platy crystals resembling similar crystallizations of baryte and reaching three-quarters of an inch in diameter.

(4) Stumpy, double pyramidal crystals with small prism faces generally revealing composite growth on the pyramid faces. These measure about one half inch across and are less common than the other three types.

Matlockite occurs in cavities of galena and compact baryte ('cawk'), both sometimes altered, and is often associated with phosgenite, anglesite, cerussite, blende, and colourless fluorite.

The specimen chosen for complete study including chemical analysis consisted of tabular fragments previously broken from a platy aggregate ($2 \times 1 \times 1/8$ inch) showing good basal cleavage. The cleavage fragments picked out for chemical analysis were carefully examined for any enclosures of fluorite but none could be observed.[1] Mr. Hey also failed to detect even a trace of calcium. It is certain, therefore, that the fluorine content found by chemical analysis is proper to matlockite and no part of it can be attributed to admixed fluorite. Mr. Hey's analysis and density determinations are given in table 1. The fluorine was determined by precipitation as lead fluochloride. Table 1 also shows the results of the only other two recorded chemical analyses performed on matlockite, one by R. A. Smith on Greg's original material (2) and the second by C. Rammelsberg (4) on material sent to him by W. G. Lettsom from Cromford. Comparing all three analyses with the theoretical figures for lead fluochloride, PbFCl, and lead oxychloride Pb_2OCl_2, it is obvious that the chemical distinction of these two compounds can scarcely be based on the small differences in lead and chlorine content but only on the detection and estimation of a few per cent. of fluorine. It is not surprising, therefore, that the earlier analysts completely overlooked this component and failed to arrive at the true composition of matlockite.

[1] Mr. Arthur Russell tells me that he possesses crystals of matlockite enclosing small colourless cubes of fluorite.

TABLE 1. *Chemical analyses and densities of matlockite from Cromford, Derbyshire.*

	1.	2.	3.	4.	5.
Pb ...	79·55	82·35	82·16	79·24	82·73
F ...	7·11	[3·56]	[4·46]	7·21	—
O ...	—	—	—	—	3·13
Cl ...	13·44	14·08	13·38	13·55	14·14
Total ...	100·10	100·00	100·00	100·00	100·00
Density	7·05	7·21	5·3947	—	—

1. Analyst, M. H. Hey, 1934. B.M. 54607.
2. Analyst, R. A. Smith (2), 1851.
3. Analyst, C. Rammelsberg (4), 1852; density figure much too low.
4. Theoretical figures for matlockite, PbFCl.
5. Theoretical figures for lead oxychloride, Pb_2OCl_2.

The figures in square brackets obtained by subtracting the sum of the lead and chlorine percentages from 100 were assumed by Greg and Rammelsberg to represent the oxygen content. They are now rightly included as fluorine.

Crystallography.—The specimen of matlockite chosen for chemical analysis carried several minute plates suitable for X-ray and goniometric study. The following faces were observed (001), (110), (100), (101), and (111). The predominant forms on all platy crystals so far examined are (001) and (110); the (100) faces are always much smaller than (110). The basal plane is often imperfect and sometimes possesses a wavy surface probably due to vicinal growths. The cleavage face (001), however, yields good light-reflections. The angles (110) : (111) and (100) : (101) were measured on several crystals and the mean axial ratio found to be $a : c = 1 : 1{\cdot}763$, a value in close agreement with the ratio 1 : 1·7627 deduced from Greg's measurements.

X-ray examination.—Rotation photographs of one of the measured crystals were then taken about the [001], [100], and [110] axes. Layer-line measurements gave approximate unit-cell dimensions, and high order equatorial diffractions yielded the more accurate values a 4·09, c 7·21 Å. The ratio c/a is identical with the axial ratio obtained by goniometry. Assuming the unit cell contains 2PbFCl the calculated density of matlockite is 7·16 approximately the mean of Greg's and Hey's observed values. These cell dimensions are identical with those obtained by Nieuwenkamp and Bijvoet (5) from a powder photograph of artificial PbFCl (d 7·05). At this stage therefore powder photographs of artificial PbFCl and matlockite (B.M. 54607) were taken. They also were found to be identical with each other. The identity of matlockite and artificial PbFCl is therefore well established.

It is necessary, however, still to test whether the conclusions of Nieuwenkamp and Bijvoet as to the space-group and crystal-structure of PbFCl are supported by X-ray photographs of single crystals of matlockite. A Laue photograph of a minute crystal along the [001] axis shows a tetragonal axis of symmetry and planes of symmetry parallel to [100] and [110]. This limits the permissible space-groups for the mineral to the D_{2d}, C_{4v}, D_4, and D_{4h} classes. Rotation photographs were then completely indexed. The diffractions (100), (210), (300), (320), (410), (430), and (500) are all definitely absent even after long exposures; thus ($hk0$) is halved for $(h+k)$ odd; no other systematic halvings could be observed. The space-group is therefore limited unequivocally to D_{4h}^7.

The unit cell of matlockite contains two lead, two chlorine, and two fluorine atoms. Of these the lead atoms with the highest atomic number will contribute most to X-ray diffractions. They will necessarily occupy one of the three twofold positions possible in the space-group D_{4h}^7. These positions are (*a*) $\frac{1}{2}00$, $0\frac{1}{2}0$; (*b*) $\frac{1}{2}0\frac{1}{2}$, $0\frac{1}{2}\frac{1}{2}$; and (*c*) $00u$, $\frac{1}{2}\frac{1}{2}\bar{u}$; and are simply derived from the alternative coordinates given in the tables of Niggli and Wyckoff. In the latter setting the alternating fourfold axes pass through the corners and centre of the unit cell, whereas in the setting adopted here and by Nieuwenkamp the simple fourfold axes occupy these positions in accordance with Astbury's figure of the symmetry elements of the space-group. The lead atoms cannot occupy positions *a* and *b*, for in both cases they would contribute nothing to the intensities of diffractions from planes of the type (hkl) when $(h+k)$ is odd. From table 2 it will be seen that many such planes, e.g. (211), give strong diffractions. Successive orders of (001) should also be strong, whereas the four, sixth, and eighth are weak. If, however, the lead atoms be placed in positions $00u$, $\frac{1}{2}\frac{1}{2}\bar{u}$, with u = about 0·2, then the correct sequence of intensities from the basal plane can be accounted for. If next the chlorine atoms be placed either in *a* or *b* positions, ($hk0$) diffractions for $(h+k)$ odd should be weaker than those for $(h+k)$ even. Moreover, Nieuwenkamp and Bijvoet (6) have tested this possibility for the isomorphous compound PbFBr where the larger scattering power of the bromine atom would produce marked differences in the two types of diffraction. No such differences exist. A study of the structures of the analogous compounds BiOCl, BiOBr, and BiOI by the present writer[1] has also shown that the halogen atoms do not

[1] Unpublished.

occupy either the a or b positions. The observed intensities can be explained if the Cl atoms be placed at c with $u = 0{\cdot}65$. Whereas both the lead and chlorine atoms can be placed with certainty, the positions suggested for fluorine cannot be determined from the diffraction intensities. The length of the diagonal of the base of the unit cell is a little more than twice the diameter of a fluorine ion; this supports their proposed location at a. Moreover, the lead and fluorine atoms of the cubic form of lead fluoride PbF_2 occupy the same relative positions. The structure of matlockite is therefore defined by the atomic positions:

Pb	...	...	$00u$,	$\frac{1}{2}\frac{1}{2}\bar{u}$;	$u=0{\cdot}208$.
Cl	...	...	$00v$,	$\frac{1}{2}\frac{1}{2}\bar{v}$;	$v=0{\cdot}65$.
F	...	...	$\frac{1}{2}00$,	$0\frac{1}{2}0$.	

and except for a slight increase in the parameter of the lead atoms is in agreement with Nieuwenkamp and Bijvoet's proposed structure for artificial lead fluochloride, PbFCl.

TABLE 2. *Observed intensities and calculated structure-factors for rotation photographs of a single crystal of matlockite.* (B.M. 54607.)

Diffracting plane.	$\frac{\sin\theta}{\lambda}$	Observed Intensity.	Structure-factor S'.	Diffracting plane.	$\frac{\sin\theta}{\lambda}$	Observed Intensity.	Structure-factor S'.
(001)	0·069	m	24·2	(400)	0·488	m	56·6
(002)	0·139	vs	−59·6	(410)	0·504	absent	0
(003)	0·208	mw	−29·3	(420)	0·547	s	53·1
(004)	0·278	w	27·4	(430)	0·613	absent	0
(005)	0·347	s	58	(500)	0·612	absent	0
(006)	0·417	vvw	10	(510)	0·624	vs	45·1
(007)	0·486	m	−49·5	(211)	0·278	s	40·4
(008)	0·555	vw	−17·5	(212)	0·303	s	50·6
(009)	0·625	ms	29·0	(213)	0·340	m	−46·2
(100)	0·122	absent	0	(214)	0·386	m	−56·3
(110)	0·173	vs	75·3	(221)	0·353	vvw	6·4
(200)	0·244	s	80·4	(222)	0·373	m	−48·9
(210)	0·274	absent	0	(223)	0·404	vw	−14·9
(220)	0·346	s	68·7	(224)	0·443	nil	13·3
(300)	0·366	absent	0	(301)	0·374	mw	35·9
(310)	0·387	s	57·4	(302)	0·392	mw	44·5
(320)	0·441	absent	0	(303)	0·422	w	−41·2
(330)	0·519	m	49·4	(304)	0·460	w	−51·8

Cu−Kα radiation with nickel filter was used, $\lambda = 1{\cdot}539$ Å.

s = strong, m = medium, w = weak, vw = very weak.

The S' values are calculated from the following expressions:—

For $h+k$ even and both h and k even:—$S' = \text{Pb}\cos 2\pi ul + \text{Cl}\cos 2\pi vl + \text{F}$.

For $h+k$ even and both h and k odd:—$S' = \text{Pb}\cos 2\pi ul + \text{Cl}\cos 2\pi vl - \text{F}$.

For $h+k$ odd:—$S' = \text{Pb}\sin 2\pi ul + \text{Cl}\sin 2\pi vl$.

Table 2 shows the general agreement of observed intensities and calculated structure factors for a large number of diffractions. Fig. 1 gives, diagrammatically, successive sections of the structure across the *c* [001] axis and shows that the structure is of the layer type. This conclusion is fully supported by the good *c* cleavage. The cleavage flakes, however, are extremely brittle and this probably explains

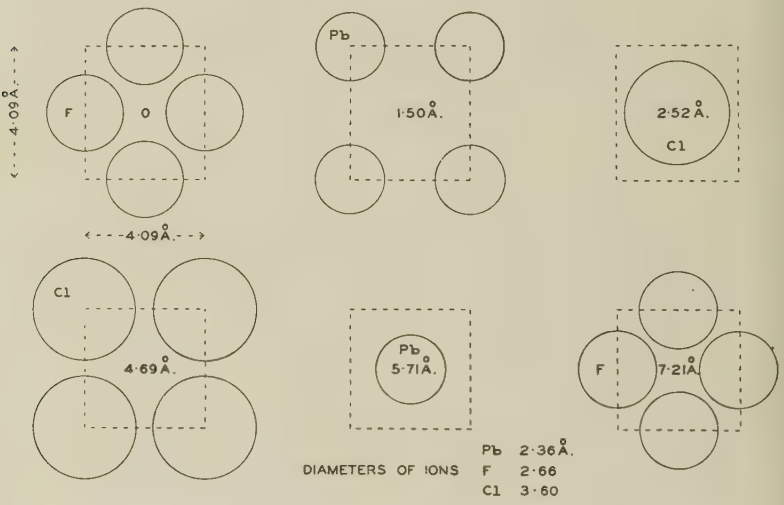

FIG. 1. Sections of the crystal-structure of matlockite at successive levels in the unit cell at the heights indicated along the *c*[001] axis.

Greg's statement that matlockite 'cleaves, but not readily, parallel to P'. Rammelsberg notes more accurately that the mineral has 'only one, though very complete cleavage'. It is reasonable to expect that in a simple layer structure of this type there will be a high negative birefringence because the light vibrations should travel more slowly across a layer than in a direction perpendicular to it.

Optical data.—Larsen (7) has determined the approximate refractive indices of matlockite from Cromford but gives no details of his method. His values are ω 2·15 ϵ 2·04. He also describes the mineral as 'perceptibly uniaxial negative' and lists it as both biaxial and uniaxial. It was found possible to grind and polish a prism from a cleavage plate selected from similar material used for chemical analysis and X-ray work. The plate chosen is 2·5 mm. thick, quite transparent, and gives a perfect uniaxial interference-figure with

negative sign. The prism angle is 37° 17′ and the refracting faces enclose angles of 89° 31′ and 91° 43′ with the (001) cleavage. The correction to be applied to the values of ϵ has been calculated and is less than 0·0002. The refractive indices can be measured accurately only to the third place of decimals so that the correction for the slightly mis-cut prism faces is negligible.

Table 3 shows that the refractivity, birefringence, and dispersion of matlockite are all high. Larsen's value for ω is in good agreement, but his value for $\omega - \epsilon$ appears to be too low. The only other optical measurement recorded for matlockite from Cromford, Derbyshire appears in Greg's original paper, where Prof. W. H. Miller stated 'A slice parallel to the plane *c*, 0·0204 inch thick, being placed in the polarizing instrument having the planes of polarization of the polarizer and analyser at right angles to each other, the angular radius of the first blue ring in air was found to be 22° 81′.' Assuming the values of ω and ϵ for λ 4861 given in table 3 the calculated angular radius of the first light ring is 23°. Miller's measurement therefore constituted the first proof of the high birefringence of matlockite.

TABLE 3. *Refractive indices of matlockite for various wave-lengths.* (B.M. 54607.)

Line.	Wave-length.	ω.	ϵ.	$\omega-\epsilon$.	Probable limits of error in $(\omega-\epsilon)$.
Li_α	6708 Å.	2·124	1·991	0·133	± 0·002
H_α(C)	6563	2·127	1·994	0·133	0·002
—	6330	2·133	1·998	0·135	0·001
—	6180	2·136	2·000	0·136	0·001
—	5920	2·143	2·006	0·137	0·001
Na	5893	2·145	2·006	0·139	0·001
—	5640	2·152	2·012	0·140	0·001
—	5530	2·156	2·014	0·142	0·001
Tl_α	5350	2·164	2·021	0·143	0·001
—	5270	2·166	2·022	0·144	0·002
—	5180	2·172	2·026	0·146	0·002
H_β(F)	4861	2·191	2·039	0·152	0·002
—	4800	2·195	2·042	0·154	0·003
—	4480	2·219	2·057	0·162	0·003
H_γ(G′)	4340	2·23	2·07	0·16	0·005
—	4250	2·24	2·07	0·17	0·005

Dispersive power, $P=(n_F-n_C)\,/\,(n_{Na}-1)$:—
$P_\omega = 0{\cdot}056$, $P_\epsilon = 0{\cdot}045$.

A large number of cleavage plates of varying thicknesses were then examined in convergent light, and Larsen's suggestion that

biaxial figures can be observed with this mineral was confirmed. The same plate showed uniaxial and biaxial figures which sometimes changed their character when the plate was viewed from the opposite direction. The irregularity of the effect precluded macroscopic twinning as an explanation. The biaxial character of a tetragonal substance can, however, be due to: (1) True orthorhombic symmetry with mimetic twinning; (2) strain; or (3) sub-parallel growth. The first possibility is rendered improbable by the coincidence of all high-order (*hkl*) and (*khl*) spots on the X-ray rotation photographs. It would be possible to distinguish a difference of 0·001 Å between the *a* and *b* dimensions of matlockite if it were pseudo-tetragonal.

If the biaxial nature is due to strain then it might be possible by annealing biaxial matlockite to restore the uniaxial character. Having determined the melting-point of matlockite as $490° \pm 10°$ C., some biaxial fragments were very slowly heated to 450° C. kept there for an hour and then slowly cooled down to air-temperature. This procedure follows closely the operation of annealing glass. Most of the thicker plates of matlockite shattered violently at temperatures well below 200° C. All the thin plates left at the end of the experiment gave uniaxial pictures. A few uniaxial plates about 1 mm. thick were then carefully heated to about 400° C. and cooled rapidly on an iron plate or in water. Those plates which were not shattered by the process retained perfect uniaxial figures. It is unlikely, therefore, that the biaxial character of some plates is due to strain. I had observed that many of the plates giving definite biaxial figures were not bounded by parallel (001) faces but appeared to be sub-parallel growths. Two uniaxial cleavage flakes were then mounted on a glass wedge and examined in convergent polarized light. The interference-figure obtained gave a small value of 2E. These tests make it probable therefore that the biaxial character of matlockite is anomalous and depends on the angle of tilt between single crystal layers.

The work of Nieuwenkamp and the present authors has now established the true chemical composition and crystal-structure of matlockite. The mineral is not, as might have been supposed on purely chemical grounds, a mixed crystal of lead fluoride PbF_2 and lead chloride $PbCl_2$. One of the dimorphous forms of PbF_2 is isomorphous with $PbCl_2$, but both are orthorhombic and possess crystal-structures intermediate in type between that of fluorite and a layer structure. Matlockite can be directly compared, however, with

bismuth oxychloride (BiOCl).[1] They are isostructural and in a limited sense isomorphous. That is, PbFCl and BiOCl do not form mixed crystals but may be expected to form oriented parallel growths with each other. The crystal-structure of litharge PbO, the tetragonal form of lead oxide, is not known with absolute certainty. Its high negative birefringence and platy cleavage suggest, however, a layer structure and it is significant that the base of the unit cell of litharge has approximately the same dimensions as those of matlockite and bismuth oxychloride. The data given in table 4 show the chemical, crystallographic, structural, and optical relationships between matlockite and the above-mentioned compounds. Although no mineral with the composition Pb_2OCl_2 is known to exist, the compound has been made artificially and was one of the early substitutes for white-lead paint. R. Ruer (8) has noted that artificial Pb_2OCl_2 grows in the form of needles. Such a crystal habit does not suggest identity of artificial Pb_2OCl_2 with tabular matlockite, but this point was missed by Ruer. A powder photograph of artificial Pb_2OCl_2 prepared by M. H. Hey has been taken and found to be much more complex than the matlockite pattern. So far single needles suitable for X-ray work have not been successfully prepared. The true symmetry and crystal-structure of this artificial compound, once thought to be identical with matlockite, remain unknown.

In conclusion, it should be said that no evidence so far exists showing that fluorine has been overlooked in any other mineral hitherto regarded as an oxychloride. For instance, the mode of occurrence of mendipite and the absence of fluorine-bearing minerals in the Mendip Hills render it unlikely that mendipite contains any fluorine. To place the matter quite beyond doubt some fragments of a specimen of mendipite studied by Dr. L. J. Spencer (13) and analysed by Prof. E. D. Mountain have been tested for fluorine with a negative result. A preliminary X-ray study of this mineral shows that its crystal-structure is quite different from that of matlockite (see table 4). The rare minerals laurionite, paralaurionite, fiedlerite, and penfieldite are products of the action of sea-water upon slag-heaps of ancient workings at Laurion, Greece, and the presence of fluorine is improbable. So-called matlockite from this locality has been noted both by G. F. Herbert Smith (14) and by A. Lacroix, (15) but this could not be confirmed. The latter gave a full account of the

[1] The crystal-structure of BiOCl, BiOBr, and BiOI shortly to be published by the author.

TABLE 4. *X-ray and optical data for matlockite and certain related compounds.*

Compound.	Unit-cell contents.	Unit-cell dimensions *a.*	*b.*	*c.*	Birefringence.	Optical Orientation.
Matlockite ...	2PbFCl	4·09	4·09	7·21 Å.	−0·139 (Na)	optic axis ⊥ cleavage (001)
Artificial bismuth oxychloride	2BiOCl	3·889	3·889	7·374	negative large	optic axis ⊥ cleavage (001)
Litharge (9) ...	2PbO	3·99	3·99	5·01	−0·13 (Li)	optic axis ⊥ cleavage (001)
Artificial (10) lead chloride	$4PbCl_2$	4·53	7·61	9·03	0·0604	Bx_o ⊥ cleavage (001)
Artificial (11) lead fluoride, α form	$4PbF_2$	3·80	6·41	7·61	?	?
Artificial (12) lead fluoride, β form	$4PbF_2$	5·93	5·93	5·93	isotropic	——
Mendipite ...	$4(Pb_3O_2Cl_2)$	9·50	11·87	5·87	0·07	Bx_a ⊥ (100)

optics of a mineral which can hardly be reconciled with the optical properties of matlockite from Cromford, Derbyshire. Lacroix described square tablets showing four sectors in twin position each giving a negative biaxial figure with 2E 55°. A. de Schulten also studied crystals from the same material and observed in addition some uniaxial plates but no chemical tests were carried out. I am indebted to Professor Lacroix for the loan of one of the original specimens from Laurion, Greece, upon which he identified matlockite. The specimen is a small fragment of scoriaceous material carrying many crystals of laurionite, but a careful search has so far failed to reveal any mineral which answers to his description. An X-ray study of all the Laurion minerals is needed; it may prove that one of them at least is identical with one or other of the artificial lead oxychlorides.

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Lusakite, a cobalt-bearing silicate from Northern Rhodesia.

(With Plate XXIV.)

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[Read June 7, 1934.]

Discovery and Occurrence.

THIS interesting new mineral was discovered by the first author in February 1933 whilst in the employment of the British South Africa Company Limited as a field geologist to the Rhodesia Minerals Concession Limited under the direction of Dr. J. Austen Bancroft. The locality, longitude 29° 29′ E. and latitude 15° 27′ S., is about eighty miles east of Lusaka, the new capital of Northern Rhodesia, after which the mineral is named. The central African plateau has here been cut back from the northern escarpment of the Zambezi rift valley, about 10 miles to the south, producing a rugged topography varying from 1,000 feet to 4,000 feet in altitude.

The general geological setting consists largely of granite-gneisses and amphibolites, with subsidiary epidosites, mica-schists, banded ironstones, and quartzites. There is a widespread mineralization of quartz-pyrite and quartz-tourmaline veins carrying low values in gold. The suite of rocks makes an interesting study in petrogenesis which it is hoped to describe elsewhere. The new mineral occurs in a rock of gneissoid appearance in which it is intimately associated with quartz, kyanite, and magnetite (pl. xxiv, fig. 1). The average approximate proportions of these minerals by weight and their quantity variations are as follows:

Lusakite	5–40%	...	average 30%
Quartz	10–25	...	„ 12
Kyanite	0–10	...	„ 3
Magnetite	40–65	...	„ 55

Parallel to the foliation of the rock are vuggy streaks in which well-developed crystals are found. This quartz-magnetite-lusakite-rock was found on a hillside as a few well-jointed float boulders obviously representing a broken down outcrop and indicating a vein or bed a few inches in thickness and extending possibly for thirty yards along the strike. Associated with these boulders were found larger pieces of a very interesting cordierite-anthophyllite-rock thought to be genetically connected with the lusakite-rock.

The average grain size of the mineral is about $2 \times 1 \times \frac{1}{2}$ mm. and individual crystals range from microscopic dimensions to 5 mm. long. In hand-specimens the colour is black, but minute crystals are deep cobalt-blue by transmitted light. The mineral gives a light blue streak, so that hand-specimens of the lusakite-bearing rock often show blue patches due to impact and abrasion. It is brittle, with subconchoidal fracture; the hardness is $7\frac{1}{2}$ and the lustre vitreous.

Microscopic Characters.—When viewed in thin sections the mineral has a vivid cobalt-blue colour in ordinary light, probably the most intense blue yet observed in a thin section of any mineral. It rarely shows crystal boundaries unless the section includes one of the vuggy portions of the rock referred to above (fig. 2). There is a distinct cleavage parallel to (010) and a less distinct one parallel to (100). No twinning has been observed. The refractive index is high, about 1·74, giving a marked relief in thin section. The deep body-colour somewhat masks the birefringence, but all sections show straight extinction parallel to cleavage cracks. Lusakite is strongly pleochroic in tints varying from light cobalt-blue to violet and even dark wine-red in thick sections; α[010] cobalt-blue, β[100] violet-blue, γ[001] violet. A biaxial interference-figure has been observed in an accurately orientated basal section, but 'eyes' lie outside the field suggesting a large value of 2V, whilst sections at right angles to an optic axis show a 'compass needle' isogyre, also indicating the closeness of 2V to 90°.

Under a high power blebs of 'myrmekitic' quartz of various shapes can frequently be observed sometimes arranged in fan-like aggregates (fig. 3). Two other minerals which are present in minor amounts are rutile, which occurs as inclusions in the kyanite, and fibrolite, seen as minute radiating clusters at the edges of the patches of quartz.

Chemical Composition.—Lusakite is essentially an aluminium silicate carrying cobalt, iron, nickel, and magnesium, and is unique amongst the silicates in its content of cobalt. A preliminary qualitative

analysis was made using a quartz-wedge spectrograph which facilitated the quantitative analysis carried out by Dr. A. W. Groves on two separate samples. The first sample was obtained by crushing the rock and hand-picking the fragments of lusakite, which, however, carried a certain amount of magnetite and quartz as inclusions. A preliminary determination of the specific gravity of this material, using an ordinary pyknometer and also a Jolly balance, gave $3{\cdot}76 \pm 0{\cdot}05$. The second sample was obtained by powdering rock containing lusakite but not kyanite, abstracting magnetite with a magnet and then boiling repeatedly with hydrochloric acid to dissolve the remaining magnetite; the mineral was then separated from quartz by scattering the powder over the surface of bromoform contained in a large funnel and repeating the operation several times. The specific gravity of this pure powder was determined more accurately by the Ellsworth silica pyknometer using carbon tetrachloride and leaving the mineral immersed under reduced pressure for twelve hours before weighing; the value obtained was $3{\cdot}767 \pm 0{\cdot}005$.

The chemical stability of lusakite is illustrated by the absence of alteration under tropical conditions of weathering; in the laboratory all acids including hydrofluoric acid are without effect upon it. It is infusible in the Bunsen flame but yields a black bead in an electric arc. Decomposition and solution can be brought about, however, by fusion with sodium carbonate before a strong blowpipe flame followed by extraction with hydrochloric acid.

The determination of ferrous iron proved extremely difficult on account of the chemical resistance of lusakite even to a mixture of hydrofluoric and sulphuric acids. Leaching with such a mixture three times in succession yielded values that must be considered as only approximate. Since the mineral is not taken into solution it is probable that only the outer portion of each particle of the powder is acted on and freed of its ferrous iron.

Table 1 shows the results of chemical analysis of the two samples. The second analysis, made on the more carefully prepared sample, leads approximately to the formula

$$H_2O.2(Co,Ni)O.FeO.MgO.9(Al,Fe)_2O_3.8SiO_2$$

or $$H_2O.4R^{II}O.9Al_2O_3.8SiO_2 = H_2R^{II}_4Al_{18}Si_8O_{48}.$$

This corresponds with the formula $H_2O.4FeO.9Al_2O_3.8SiO_2$ deduced by F. Hörner[1] for staurolite.

[1] F. Hörner, Beiträge zur Kenntnis des Stauroliths. Inaug-Diss. Heidelberg, 1915. [Min. Abstr., vol. 1, p. 395.]

TABLE 1. *Chemical analyses of lusakite.*

	I.	Mol. ratios.			II.	Mol. ratios.		
SiO_2 ...	27·07	0·451	0·461	9·75	...27·23	0·453	0·459	7·75
TiO_2 ...	0·80	0·010			... 0·50	0·006		
Al_2O_3 ...	48·15	0·472	0·540	11·34	...50·72	0·497	0·528	8·905
Cr_2O_3 ...	trace	—			... n.d.	—		
Fe_2O_3 ...	10·83	0·068			... 4·96	0·031		
FeO ...	2·22	0·031	0·189	4·00	... 3·42	0·048	0·237	4·00
NiO ...	0·53	0·007			... 0·89	0·012		
CoO ...	6·79	0·091			... 8·48	0·113		
MnO ...	trace	—			... 0·08	0·001		
MgO ...	2·44	0·060			... 2·56	0·063		
CaO ...	nil	—			... nil	—		
$H_2O+110°$	1·00	0·056	0·056	1·17	... 1·19	0·066	0·066	1·11
$H_2O-110°$	0·35	—			... nil			
S ...	0·07				... —			
	100·25				100·03			
Sp. gr. ...	3·76				3·767			

Crystallography. The crystals are generally tabular in habit, but some detached for goniometric and X-ray work were practically equidimensional prisms. The only forms observed with certainty are (010) and (110), the former usually predominating. Optical reflections from the faces are poor and there is vicinal plane development. Also some crystals show striated tabular (010) faces due to the alternation of (010) and (110). Accurate interfacial angles were therefore difficult to obtain, but so far as the prism-zone is concerned crystals of the mineral appear to possess a plane of symmetry parallel to (010). The average values obtained from three crystals for the angle (010) : (110) is 64° 37′ corresponding to an axial ratio $a : b = 0{\cdot}474 : 1$. Owing to the absence of definite terminal faces the ratio $c : b$ could not be obtained by direct goniometric measurement.

X-ray investigation.—One of the smaller crystals used for goniometric measurements was used for X-ray work. Laue photographs along the three axes of the crystals show in each case two planes of symmetry at right angles. Rotation photographs about these three directions yield the dimensions a 7·86, b 16·62, c 5·65 Å. The limits of error for these measurements are $\pm 0{\cdot}01$ Å. for a and c and 0·03 Å. for b. The axial ratios calculated from the unit-cell dimensions are $a : b : c = 0{\cdot}473 : 1 : 0{\cdot}340$. The $a : b$ ratio is in satisfactory agreement with the goniometric value. A series of oscillation photographs about [100], [010], and [001] were indexed and the following halvings found: all (hkl) for $h+k$ odd and all $(0kl)$ for $k+l$ odd. A special

search was made for any weak spots on the equator of the photographs about the [100] axis which defied the latter halving. None could be found. Moreover, no weak layer-lines could be detected requiring the doubling of any of the unit-cell lengths. The space-group of the mineral is therefore V_h^{17}.

Crystal-structure.—The chemical analysis, the X-ray data, and the optical properties all show that lusakite is closely related to staurolite. The intensity differences of spots on rotation photographs of each mineral about the [001] axis are indeed very small so that we can be certain that the crystal-structures are also practically identical. Below are listed the known crystallographic and X-ray data for staurolite and lusakite.

Mineral.	Space-group.	Unit-cell dimensions a.	b.	c.	Calculated axial ratio.
Lusakite ...	V_h^{17}	7·86	16·62	5·65	0·473 : 1 : 0·340
Staurolite [1] ...	V_h^{17}	7·81	16·59	5·64	0·471 : 1 : 0·339
Staurolite [2] ...	V_h^{17}	7·82	16·52	5·63	0·473 : 1 : 0·341

The axial ratio c of staurolite referred to the axes adopted by Dana has to be halved. The faces indexed according to those axes as (101) and (011) should be transformed to (201) and (021) respectively. The axial ratios based on the measurements of W. Phillips (1823) therefore become $a : b : c = 0{\cdot}4734 : 1 : 0{\cdot}3414$, and those on F. Hörner's measurements (1915) $a : b : c = 0{\cdot}4734 : 1 : 0{\cdot}3410$, both in very close agreement with the X-ray values. Náray-Szabó has proposed a sandwich type of crystal-structure for staurolite consisting of blocks of kyanite interleaved with layers of $Fe(OH)_2$. This structure is based upon an 'ideal' formula $H_2FeAl_4Si_2O_{12}$ which may be written $[Fe(OH)_2 + 2Al_2SiO_5]$. He rejected the formula of S. L. Penfield and J. H. Pratt [3] and also that of F. Hörner [4] as unsatisfactory. If, however, the actual chemical analyses and density data of Penfield and Pratt and of Hörner are used as a basis of calculation it is significant that the number of oxygen atoms per unit cell of staurolite is practically constant and equal to 48. From table 2 it is seen that the maximum variation in the oxygen figures for staurolite and lusa-

[1] G. M. Cardoso, Zeits. Krist., 1928, vol. 66, p. 485. [M.A. **3**–529, **4**–111.]

[2] S. Náray-Szabó, Zeits. Krist., 1929, vol. 71, p. 103. [M.A. **4**–160.]

[3] $HFeAl_5Si_2O_{13}$. S. L. Penfield and J. H. Pratt, On the chemical composition of staurolite... Amer. Journ. Sci., 1894, ser. 3, vol. 47, p. 81.

[4] $H_2Fe_4Al_{18}Si_8O_{48}$. F. Hörner, 1915, loc. cit.

kite is 1·5 %. Since errors from three different experimental determinations, viz. chemical analysis, density, and X-ray work, are involved the closeness of approach of the oxygen figure to an integral number 48 is reasonable. The numbers of atoms other than oxygen in the unit cell have been calculated on a basis of 48 oxygen atoms per unit cell and are included in table 2.

TABLE 2. *Atomic contents of unit cell of lusakite and staurolite.*

	1.	2.	3.	4.	5.	6.	7.
Sp. gr. ...	3·767	3·773	3·728	3·748	3·775	3·759	3·753
O	47·3	48·6	48·3	48·4	48·4	48·0	47·9
Si	7·75	7·71	7·70	7·68	7·76	7·75	7·80
Ti	0·11	—	—	—	—	0·16	0·15
Al	17·01	17·45	17·70	17·39	17·79	17·61	17·00
Fe^{III} ...	1·06	1·01	0·59	0·59	0·58	0·49	0·38
Fe^{II} ...	0·81	2·26	2·44	2·60	2·91	2·97	3·11
Ni	0·20	—	—	—	—	—	—
Co	1·93	—	—	—	—	—	—
Mn ...	0·02	0·08	0·14	0·12	—	—	—
Mg ...	1·09	1·10	0·76	0·75	0·80	0·74	0·86
H	2·26	3·75	4·12	4·04	3·16	2·73	3·78

1. Lusakite, Lusaka, Northern Rhodesia. A. W. Groves, 1934.
2. Staurolite, Burnsville, North Carolina.
3. ,, Windham, Maine, U.S.A. } S. L. Penfield and
4. ,, St. Gotthard, Switzerland. } J. H. Pratt, 1894.
5. ,, Lisbon, New Hampshire.
6. ,, Aschaffenburg, Bavaria. } F. Hörner, 1915.
7. ,, Pizzo Forno, St. Gotthard.

Comparing these figures for staurolite with those for the unit-cell content proposed by Náray-Szabó it is clear that chemical analyses reveal a much higher content of aluminium atoms and only half the number of hydroxyl groups. Previous workers have generally considered that the accuracy of chemical analyses of staurolite is invalidated by the presence of inclusions of quartz and kyanite with which latter mineral staurolite readily forms parallel intergrowths. Lusakite shows under high magnification myrmekitic inclusions of quartz; and intergrown kyanite may also be present. The silicon content for both minerals is, however, almost constant and ranges from 7·68 to 7·80 atoms per unit cell. This is evidence for the comparative unimportance of the inclusions in the chemical analyses, since there is already a slight deficiency in the amount of silicon (8 atoms) required by X-ray theory.

The total number of atoms in the unit cell of lusakite excluding

oxygen is 32·2. Since the space-group permits only fourfold positions in the crystal-structure, this figure should be 32. The contents of the unit cell are therefore $8[RO.Al_2SiO_5]$, if it is assumed that the deficiency in silicon is made up by aluminium, R including Fe, Co, Ni, Mg, Al, and H. The aluminium atoms have a sixfold co-ordination and it is probable that each atom comprised in the layers 4RO is associated with four shared oxygen atoms and two hydroxyl groups. The contents of the unit cell may then be written $[4(Fe,Mg,Co,Ni)O.H_2Al_2O_4]+[8Al_2SiO_5]$. The contents of the unit cell of staurolite lead to a similar expression, viz. $[4(Fe,Mg,Mn)O.H_2Al_2O_4]+[8Al_2SiO_5]$, which departs, however, slightly from the figures shown in table 2. The sum of all the atoms excluding oxygen ranges from 32·7 to 33·4. The space-group excludes the possibility of 33 atoms; so again the number has been rounded off to 32 with the result of decreasing the water content. This may be justified, since Penfield does not separate his analytical figure into H_2O+ and H_2O-. We are of opinion that for lusakite this interpretation of the data in table 2 is an approach to the truth. The layers of the sandwich structure proposed by Náray-Szabó for staurolite are therefore far less simple than he postulated. They do not lie midway in composition between $4Fe(OH)_2$ and $4FeO$, but must also contain two aluminium atoms. The space-group is possibly only a close approximation to V_h^{17}. The intensities of diffraction would be little influenced in a cell of this size by two weakly diffracting aluminium atoms.

Genesis.—A specially interesting feature about lusakite is the fact that it has been formed by the replacement of kyanite. Under the microscope are seen all stages of replacement from the narrow fringe of lusakite at one end of a kyanite crystal with tongues working up the cleavage (fig. 4), to crystals of lusakite containing only small residual cores of kyanite (fig. 5). Parallel growth is not sufficient to explain these observations. The partially replaced kyanite being triclinic does not always extinguish parallel to the associated lusakite. The presence of myrmekitic quartz suggests either that the replacing cobalt solution was siliceous or that it represents silica displaced from the kyanite. In support of the latter suggestion is the fact that the chemical analysis shows that the kyanite has lost nearly 3 % of its silica if the alumina content is assumed to have remained constant. Magnetite has largely cut across and replaced the kyanite and lusakite, but whether it is introduced or simply redistributed magnetite is impossible to say.

Tilley and Flett[1] have described an anthophyllite-cordierite-rock from Kenidjack, Cornwall, in the aureole of the Land's End granite, as being derived from the metamorphism of dolerites which had previously lost much of their soda by weathering. The description is closely applicable to the rock associated with the lusakite-rock.

The metamorphism of an aluminous iron laterite formed by more intense weathering might well give rise to a quartz-kyanite-magnetite-rock. The possible source of the cobalt is even more speculative and a hydrothermal origin during the later stages of metamorphism must be invoked. Again, as an alternative, the oxidation of a cobalt-iron sulphide disseminated in an argillite with subsequent burial beneath sediments followed by metamorphism would conceivably produce a quartz-magnetite-lusakite-rock. No other cobalt occurrences are known in the district, however, although a nickeliferous outcrop was found in a mass of serpentinized basic rock about ten miles to the south.

If lusakite can be regarded as equivalent to staurolite, the change from the definitely high-grade stress-mineral kyanite to the lower-grade lusakite suggests retrograde metamorphism due to relief of pressure.

Possible uses.—The very small size of the deposit precludes the exploitation of the lusakite as a source of cobalt, especially as that metal is being produced very cheaply in large quantities as a by-product of the Rhodesian copper belt. The beautiful colour is unfortunately only seen in thin section so that the mineral is of no use as a gemstone. The possibilities of using it for producing a cobalt blue in pottery and as a pigment are being investigated.

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Summary.—Lusakite is a cobalt-bearing variety of staurolite from Northern Rhodesia and has been named after the new capital of that colony. The orthorhombic crystals have unit-cell dimensions a 7·86, b 16·62, c 5·65 Å. ($a : b : c = 0{\cdot}473 : 1 : 0{\cdot}340$), space-group V_h^{17}, and

[1] C. E. Tilley and J. S. Flett, Summ. Prog. Geol. Surv. Great Britain for 1929, 1930, part 2, pp. 24–41. [M.A. 4–402.]

the unit cell contains $8[RO.Al_2SiO_5]$, where R = Fe,Co,Ni,Mg,Al,H. The empirical formula is $H_2O.4(Fe,Co,Ni,Mg)O.9(Al,Fe)_2O_3.8SiO_2$. Hardness $7\frac{1}{2}$, specific gravity 3·767, n about 1·74. The following striking features justify the new name :

1. It is the only silicate mineral containing a significant amount of cobalt (CoO 8·48 %).

2. An intense cobalt-blue colour best seen in thin sections under the microscope.

3. Strong pleochroism from light cobalt-blue to deep violet-blue.

4. It has been formed by the metasomatic replacement of kyanite.

Explanation of Plate XXIV.

Micro-sections of the lusakite-bearing rock showing quartz (clear white), magnetite (black), kyanite (clear), and lusakite (grey).

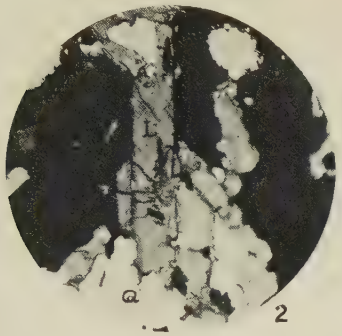
Fig. 1. Quartz-magnetite-lusakite-kyanite-rock showing foliation. ×5.

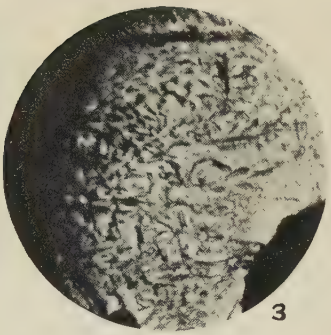
Fig. 2. Typical habit of the lusakite crystals. ×11.

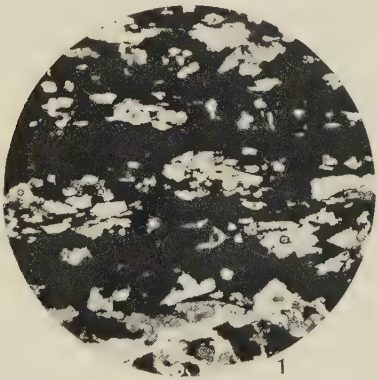
Fig. 3. Myrmekitic quartz in lusakite. ×80.

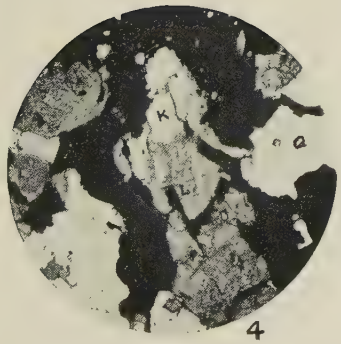
Fig. 4. Partial replacement of kyanite by lusakite. Myrmekitic quartz in lusakite (upper left). ×11.

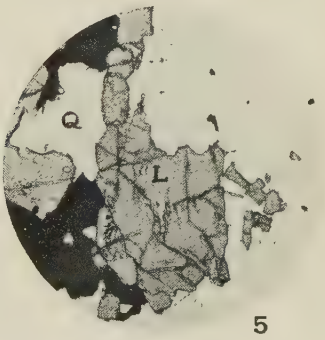
Fig. 5. Residual core of kyanite in a crystal of lusakite. ×17.











A. C. Skerl and F. A. Bannister: Lusakite.

Hydrocalumite ($4CaO.Al_2O_3.12H_2O$), *a new mineral from Scawt Hill, Co. Antrim.*

By C. E. Tilley, Ph.D., B.Sc.
Professor of Mineralogy and Petrology, University of Cambridge,
With X-ray analysis by Miss H. D. Megaw, M.A., Ph.D.
and chemical analyses by M. H. Hey, M.A., B.Sc.

[Exhibited January 25, 1934.]

In a further search for portlandite[1] amongst the vug minerals of the Scawt Hill contact-zone, attention was drawn to some infillings containing a mineral which had not previously been observed. These infillings, which occur in a larnite-rock carrying melilite-wollastonite aggregates of the hybrid zone of the contact,[2] consist of afwillite, portlandite, ettringite, and aggregates of a mineral, the light-greenish colour of which was conspicuous. This mineral is most intimately associated with afwillite, and examination of it shows it to be a hitherto unrecorded species.

Material isolated from the vugs consists of irregular fragments of colourless to light-green colour showing a perfect cleavage. The lustre is vitreous inclining to pearly on the cleavage surfaces; hardness 3, specific gravity 2·15. No material suitable for goniometrical investigation has been observed. Micro-chemical tests show the presence of abundant calcium and some carbon dioxide. In the closed tube the mineral decrepitates and gives off water. It is alkaline to litmus and dissolves completely in weak hydrochloric acid. Lime, alumina, water, and small amounts of carbon dioxide are proved on quantitative analysis, and these data show that the mineral is a new species. In allusion to its composition as an hydrated calcium aluminate ($4CaO.Al_2O_3.12H_2O$) the name hydrocalumite is proposed.

Cleavage flakes provide excellent material for optical examination. The mineral is biaxial, optically negative, and the cleavage plates

[1] C. E. Tilley, Min. Mag., 1933, vol. 23, p. 419.
[2] C. E. Tilley, Min. Mag., 1931, vol. 22, p. 439.

provide an optic picture with the acute bisectrix standing nearly normal to the cleavage taken as the base c (001); $a : \perp(001)$ is less than 3°. As confirmed by X-ray data the symmetry is monoclinic (pseudo-hexagonal). The optic axial plane lies in (010); $\beta = b$. Refractive indices determined with immersion liquids and a stage-goniometer are α 1·535, β 1·553, γ 1·557. Different fragments show some variation in the optic axial angle, but the value determined on the fragments yielding the above values of the refractive indices is 2V 24° ± 2°. When the mineral is warmed on a heating stage or heated in an oven and examined under the microscope the optic axial angle is seen gradually to decrease and the mineral becomes sensibly uniaxial at 90–95° C. On cooling, it becomes again biaxial, but the original value of the optic axial angle is not reached until some hours have elapsed. Heated to a higher temperature (160° C.), the mineral becomes turbid due to loss of water. Interference-figures obtained on this turbid material show that it is still sensibly uniaxial and only after the lapse of some weeks does it become sensibly biaxial, but the original value of the optic axial angle is not regained. Further data on the dehydration phenomena of this mineral will be given when additional material is available for continuing this interesting study.

On specially selected material Mr. M. H. Hey kindly executed in the Mineral Department of the British Museum two analyses on the small quantities available (analysis I 0·080 gram, analysis II 0·215 gram).

The following figures were obtained:

		I.	Mol. ratios.		II.	Mol. ratios.		Calculated for $4CaO.Al_2O_3.12H_2O$.
CaO	...	41·5	0·740	...	40·0	0·713	...	41·33
Al_2O_3	...	18·8	0·184	...	18·1	0·178	...	18·82
H_2O	...	38·5	2·137	...	40·3	—	...	39·85
CO_2	...	1·8	—	...		—	...	—
		100·6			98·4			100·00

In I the determination of H_2O and CO_2 was carried out by the Dittler-Hueber method [1] using the Gooch tubulated platinum crucible. In II only the total loss on ignition was determined. Each of the analyses was completed on one portion of material only. MgO, alkalis, TiO_2, P_2O_5, BaO, SrO, and BeO were tested for and found

[1] E. Dittler and H. Hueber, Zeits. Anorg. Chem., 1931, vol. 195, p. 41; 1931, vol. 199, p. 17. [Min. Abstr., vol. 5, p. 141.]

absent. The analytical data given above lead to an empirical formula $4CaO.Al_2O_3.12H_2O$.

Several hydrated calcium aluminates are known as artificial products and have repeatedly been prepared. A summary of the existing data on these artificial compounds is given by Mylius[1] who has also added considerably to our knowledge of these compounds. Mylius has prepared the compound $4CaO.Al_2O_3.13H_2O$ in the form of tabular hexagonal crystals and spherulites whose properties are given as uniaxial negative, ω 1·533, ϵ 1·522; while Assarsson[2] prepared a similar product with $13{\cdot}5H_2O$, the optical properties being given as biaxial negative, 2V 14°, α 1·510, γ 1·538. Mylius's product dried over P_2O_5 gave a product corresponding to $4CaO.Al_2O_3.12H_2O$, losing one molecule of water, and its refractive indices were thereby raised to ω 1·549, ϵ 1·533.

The Scawt Hill hydrocalumite has clearly somewhat different optical properties, for, as noted above, it is biaxial, and the birefringence is considerably greater than that of the Mylius product. The presence of significant amounts of carbon dioxide in the analysis of the natural material is doubtless in part responsible for this divergence.

X-ray analysis.

The composition of hydrocalumite, written for the moment as a hydrated oxide, is $4CaO.Al_2O_3.xH_2O$, where x is found, in two separate analyses, to be 11·6 and 11·8. In the literature, artificially prepared hydroxides of this formula are recorded, in which x varies from 11·5 to 13·5. Mylius (loc. cit.) obtained a compound with $13H_2O$, which, dried over P_2O_5, lost one molecule of water. The variable results obtained by different workers suggest that the structure is based on a composition of $4CaO.Al_2O_3.13H_2O$ and that it may lose a certain amount of water without breaking down. This dehydration may occur in a random manner so that the vacant places left are distributed statistically throughout the structure; or it may be that certain atoms in each cell are more loosely attached than others and are the first to go. Possibly some slight rearrangement of the structure accompanies the loss of water, perhaps causing lower symmetry; this idea is discussed later in the paper. It is, however,

[1] C. R. W. Mylius, Über Calciumaluminathydrate und deren Doppelsalze. Acta Acad. Aboensis, Math. et Physica, 1933, vol. 7, no. 3, 147 pp.

[2] G. Assarsson, Zeits. Anorg. Chem., 1930, vol. 191, p. 333; 1931, vol. 200, p. 391; 1932, vol. 205, p. 338. [M.A. 5–450.]

clear that the actual structure must be closely derived from one containing 13 molecules of water.

The crystal examined consisted of a cleavage flake possessing two well-marked edges parallel to the extinction directions. The cleavage plane was chosen as (001), the optic axial plane being (010). Oscillation photographs were taken about the a- and b-axes and the normal to (001), and Weissenberg photographs of the zone $[h0l]$, the layer-line $(h2l)$, and the zone whose axis was very nearly normal to (001). The photographs showed unmistakably that the crystal was monoclinic. The c-axis, chosen so as to make the smallest possible cell, gave a β-angle of 69°. The cell-dimensions are a 9·6, b 11·4, c 16·84 Å. (A pseudo-orthorhombic cell could have been chosen, three times the height, in which a and b are as before, c 47·2, β 89°.) Since the density is about 2·15, there are 4 molecules per unit cell. The only true halvings are $(0k0)$ absent for k odd, so that the space-group is either C_2^2—$P2_1$ or C_{2h}^2—$P2_1/m$. The fact that the crystal is strongly pyroelectric excludes the latter possibility, thus fixing the space-group as $P2_1$. There are in addition certain well-marked pseudo-halvings. These are: (hkl) very weak for k odd, or $h+k/2$ odd; $(h0l)$ very weak for h odd or l odd. Further, the zone [203], whose axis is the normal to (001), shows very conspicuous pseudo-hexagonal symmetry.

The general positions in $P2_1$ have the co-ordinates x, y, z; $\bar{x}, y+\frac{1}{2}, \bar{z}$. Since there are four molecules per unit cell, all the atoms may be in general positions; thus there are 52 atoms or ions each to be assigned three independent parameters. It is obvious that this problem cannot be rigorously solved. It is, however, possible to derive a good approximation to the structure by combining the X-ray data with a knowledge of the size and co-ordination of the ions involved.

The problem can be simplified by considering only a quarter of the true cell. This simplification may be made by considering the pseudo-halvings. If (hkl) were absent for k odd, the b-dimension of the cell would be halved; if (hkl) were absent for $h+k/2$ odd, this new cell would be face-centred on the c-face. The absence of $(h0l)$ for h odd is implied in this, but if $(h0l)$ were absent for l odd, there would also be a c-glide plane. This would make the space-group $C2_1/c$. The top half of the cell would then, by reason of the glide-plane, contain the same atoms as the bottom half. To obtain a first approximation to the structure it is therefore sufficient to deal with a pseudo-cell for which $a = 9{\cdot}6$, $b = 5{\cdot}7$, $c \sin\beta = 7{\cdot}86$ Å.

We have to place in this quarter-cell one molecule of $4CaO.Al_2O_3.13H_2O$, or, as it now becomes necessary to write it, $Ca_4Al_2(OH)_{14}.6H_2O$. The habit of the crystal and the excellent basal cleavage suggest that it will be profitable to consider the atoms lying in layers parallel to the basal plane. There are 24 large ions, viz. 20 oxygens (diam. 2·70 Å.) and 4 calciums (diam. 1·96 Å.); and these determine

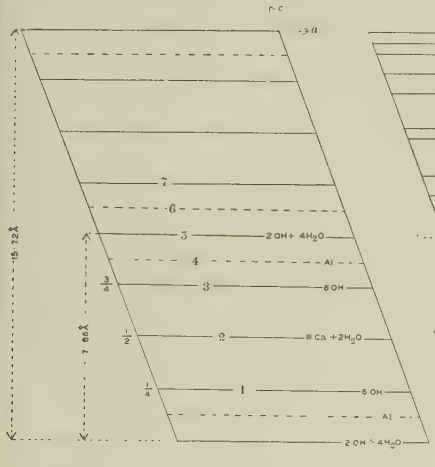


Fig. 1.

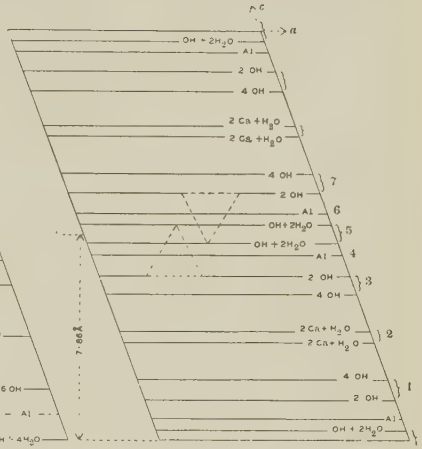


Fig. 2.

Fig. 1. Projection in the (010) plane, showing the (approximate) arrangement in layers parallel to (001).

Fig. 2. Projection in the (010) plane, showing the arrangement in layers, with the parameters given on p. 612.

the structure: the small aluminiums (diam. 1·10 Å.) fit into the interstices. The face-centring and hexagonal symmetry indicate a regular hexagonal arrangement with 6 atoms in each layer, and the cell dimensions permit this, since 6 close-packed oxygens would form a cell of base $8{\cdot}1 \times 4{\cdot}7$ Å.[2] There are then four layers in the small cell, and they must be roughly equally spaced to fit into the cell; that is, they are at heights 0, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$. This is confirmed by the intensities of the orders of the basal plane, (004) and (008) being the strongest.

So far the structure has been determined by purely geometrical arguments; physical considerations must now be introduced. By analogy with portlandite and gibbsite we may expect to find layers of cations sandwiched between layers of hydroxyl ions. If we put two planes of hydroxyl ions at $\frac{1}{4}$, $\frac{3}{4}$, they must, by Pauling's rule,

enclose a plane of cations; and since we have shown that the layer at $\frac{1}{2}$ must consist of large ions, these must be the calciums. There are, however, 6 places in the layer and only 4 calcium ions. The other 2 places might be occupied by aluminium ions; but in that case there are 2 oxygens for which there is no available room, since there are only 6 places in the layer at 0. It seems more reasonable to put 2 water molecules into the layer at $\frac{1}{2}$. For the layer at 0 we have then left 2 hydroxyl ions and 4 water molecules. There are still 2 aluminiums to be placed. Pauling's rule indicates that they must go between the layers at 0 and $\pm\frac{1}{4}$. The probable arrangement of the atoms in their layers will be discussed later. Meanwhile the structure deduced so far is shown in fig. 1.

A quantitative confirmation of the structure, and a value for the c-parameters of the atoms, may be obtained from the intensities of the basal plane (00l). These were estimated by eye on the Weissenberg photograph, and the amplitudes determined from them; the details of the method and corrections to be applied are described in the paper on gibbsite.[1] The experimental amplitudes thus deduced are given in the accompanying table along with those calculated for

	Intensity.	
Plane.	Observed (in arbitrary units).	Calculated.
(002)	18	26
(004)	46	46
(006)	26	26
(008)	45	54
(0.0.10)	38	58
(0.0.12)	10	14
(0.0.14)	<5	2
(0.0.16)	16	22

a structure with the following parameters (referred to the true cell): $2Ca + H_2O$, $\pm 0{\cdot}235$; 4OH, $\pm 0{\cdot}15$; 2OH, $\pm 0{\cdot}10$; Al, $\pm 0{\cdot}05$; $OH + 2H_2O$, $\pm 0{\cdot}025$.

These parameters, of course, are not very exactly determined; as good agreement with the observed values might be obtained by giving individual atoms slight displacements in opposite directions from the positions here assigned to them. It seems unlikely, however, that the good agreement recorded between observed and

[1] H. D. Megaw, The crystal structure of hydrargillite. Zeits. Krist., 1934, vol. 87, p. 185. [M.A. 5–471.]

calculated values could be obtained if the structure were not substantially correct. Fig. 2 shows the projection on the (010) plane of a structure with these parameters.

No attempt has been made to place the atoms more exactly by consideration of the intensities of any other planes. Where there are so many variables the work would have been too laborious, and very possibly no unique solution could have been reached. It is, however, possible to draw certain general conclusions. In the first place, from the fact that the layer of calciums with the layers of hydroxyl on either side form an approximately close-packed structure, it is established that the screw-axes cannot lie in the planes containing the calciums, but must be half-way between them, at 0, $\frac{1}{2}$. The calciums are probably distributed among the six possible positions so as to retain hexagonal symmetry. This is suggested by analogy with gibbsite and all other known AX_3 layer structures; it is confirmed by the marked pseudo-hexagonal symmetry of the crystal. It is not so easy to be certain about the positions of the aluminiums. Al can be either 4- or 6-co-ordinated; and it is possible to find an arrangement based on either of these co-ordinations which has hexagonal symmetry. There does not seem to be any good criterion to distinguish between the two possibilities, but on the whole the tetrahedral co-ordination is more plausible. In either case, the arrangement of the hydroxyls and water molecules in the adjacent layer is made so as to satisfy Pauling's rule as well as possible, by placing the hydroxyls in the positions which are nearest to the aluminiums. The two structures are shown in figs. 4 *a* and 4 *b*. The hydroxyl ions in layer 5 are probably distributed so as to make all

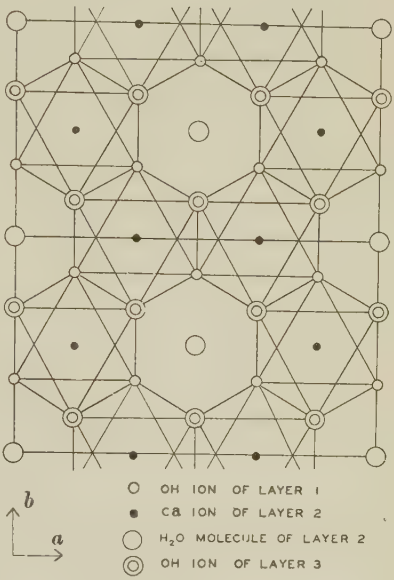


FIG. 3. Projection on (001) of layers 1, 2, 3 of fig. 1, showing oxygen octahedra round calciums.

the Al–OH distances roughly the same ; for tetrahedral co-ordination, the tetrahedra will therefore be imbricated, as shown in section by the dotted lines in fig. 2 (where no attempt has been made to draw them in their right position in the a-direction).

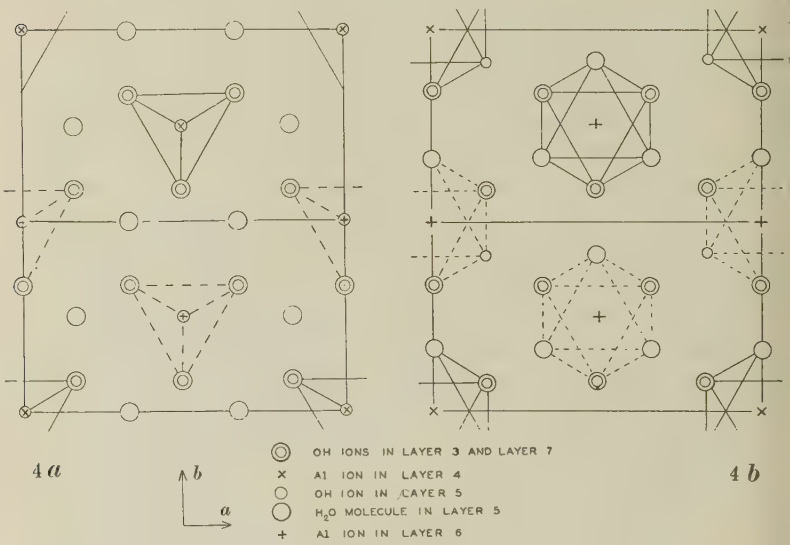


Fig. 4. Projection on (001) of layers 3–7 of fig. 1.
(a) Al in tetrahedral co-ordination.
(b) Al in octahedral co-ordination.
Full lines indicate tetrahedra and octahedra of layers 3, 4, 5.
Dotted lines indicate tetrahedra and octahedra of layers 5, 6, 7.

The structure thus determined has complete hexagonal symmetry. The actual crystal is, of course, monoclinic, but the lower symmetry can easily be achieved by small displacements of the atoms from their ideal positions. The structure proposed is in accordance with the evidence available, but it cannot claim any finality. The general principles determining structures which contain OH groups along with H_2O molecules are not sufficiently well known to provide safe guides when the straightforward determination of parameters becomes too complicated. Such general principles must first be found from simpler substances, before it will be possible to make much further progress with this structure.

We may, however, consider how the proposed structure accounts for the physical properties of the mineral. It cannot be used to

explain its optical properties, because these depend so largely on the polarization of the hydroxyl ions. On the other hand, it accounts satisfactorily for the excellent basal cleavage, and the secondary cleavage at about 60° to (100). It is also easy to see that the structure might lose water without being destroyed. The very varied results obtained by different workers on the artificial hydroxides suggest speculations about their structures and their relations to the natural mineral. Most of the substances are described as uniaxial, while some are biaxial. It seems possible that a uniaxial substance may exist, possessing the ideal structure described above. The change from the ideal hexagonal to the actual monoclinic structure is homeomorphous; and it is possible that as dehydration occurs, the water coming off either statistically or from definite positions in the cell, for certain compositions the stable structure is hexagonal and for other compositions monoclinic pseudo-hexagonal. Or again, even if a monoclinic structure is more stable for a compound with the full amount of water, it is possible that a hexagonal structure is first formed, and that the change to the other only takes place very slowly; or that different rates of crystallization affect the structure assumed. There seems to be definite evidence for this in the case of aluminium hydroxide; it has been shown that the hydroxide obtained by rapid precipitation is not the monoclinic gibbsite, but a less stable form known as bayerite. If a similar process occurs in the calcium aluminium hydroxides, it is to be expected that the naturally occurring mineral should show the stable, less symmetrical form.

Beryllium minerals (euclase and phenakite) from Africa.

By L. J. Spencer, M.A., Sc.D., F.R.S.
Keeper of Minerals in the British Museum of Natural History.

[Read June 7, 1934.]

WITH the exception of beryl, there are very few recorded occurrences of beryllium minerals in the whole of Africa. Phenakite is represented by a single small crystal from Tanganyika Territory which was described in this Magazine in 1906.[1] Chrysoberyl[2] has been found in small amount in the Somabula diamond field in Southern Rhodesia, and in Belgian Congo and Gold Coast; and gadolinite[3] in Gordonia in Cape Province. A single large crystal of euclase from Tanganyika Territory and small crystals of phenakite from South-West Africa are now to be described.

Euclase is a rare mineral of infrequent occurrence. It has been mentioned only on two occasions in this Magazine. In 1882 what was evidently believed to be a record crystal for size was described from Brazil; it measured 3·2 by 2·1 cm. and weighed 15·45 grams.[4] The largest crystal of Brazilian euclase in the British Museum collection measures $3\frac{1}{2}$ by 2 cm., and weighs $13\frac{1}{2}$ grams.[5] The new crystal from Tanganyika Territory is more than ten times the size. The second mention was of euclase from British Guiana.[6] In that paper a list was given of the six localities then known for this mineral;

[1] L. J. Spencer, Phenacite and other minerals from German East Africa. Min. Mag., 1906, vol. 14, pp. 178–183.

[2] Min. Abstr., 2–265, 2–266, 3–266, 5–399. [3] Min. Abstr., 4–475.

[4] M. Guyot, Description of a crystal of euclase, belonging to my collection. Min. Mag., 1882, vol. 5, p. 107, with crystallographic note by J. H. Collins, p. 108.

[5] A much larger crystal from the Urals was described and figured from a plaster cast by N. I. Koksharov (Min. Russlands, 1862, vol. 4, p. 100). It was $7\frac{1}{2}$ cm. long with a width of $1\frac{1}{2}$ to 2 cm., and was the sixth of the few crystals that have been found in the gold-washings in the region of the Sanarka river.

[6] L. J. Spencer, Euclase and platinum from diamond-washings in British Guiana. Min. Mag., 1924, vol. 20, pp. 186–192.

the British Guiana and Tanganyika Territory occurrences and one recently described from Trentino [1] now make nine known localities.

Euclase from Tanganyika Territory.

The specimen (B.M. 1934,116) shown in fig. 1 has been acquired for the British Museum collection of minerals from Mr. H. R. Ruggles-Brise, A.R.S.M., by whom it was found on the Lukangasi mica claim, about 5 miles south of Mikese station on the Central Railway in Morogoro district.[2] This is on an outlying hill NE. of the Uluguru Mountains. A pegmatite dike about 30 feet wide is there worked for mica, which is ruby clear or stained. The centre of the dike consists of massive quartz, and the country-rock is gneiss. The crystal was found, together with some other smaller crystals (which unfortunately were not collected), in a cavity six inches across in the pegmatite adjacent to the north wall of the dike in the open cut just above the entrance to the underground workings.

The specimen weighs 192 grams, and the main crystal is a stout prism measuring 7·2 cm. long, 3·8 cm. from back to front, and 3·5 cm. in the direction of the axis of symmetry. Attached at one end is a cluster of smaller crystals of euclase, up to 3 cm. long and 1·8 cm. across, and some cleavage plates of muscovite. The cavity was evidently lined with the smaller crystals of euclase with the one large and prominent crystal standing out and attached at one end.

The large crystal is mostly white and cloudy and not of gem quality, but on the *b*-faces it is pale bluish-green and transparent with a pearly lustre from the perfect cleavage. The cleavage is also well shown by iron staining along cracks (seen as dark lines in fig. 1). The smaller crystals are quite colourless and transparent. The large crystal is doubly terminated (a feature so rarely shown by crystals of euclase that at one time they were thought to be hemimorphic), with a full development of faces at one end, while at the attached end a few pyramid and clinodome faces are present (fig. 2). The prominent forms, determined with a contact goniometer, are *K q r*, but all the forms listed below for the smaller crystal were recognized;

[1] A. Cavinato, Nuove ricerche sull'euclasio.—Euclasio di valle Aurina, Atti (Rend.) R. Accad. Lincei, Cl. Sci. fis. nat. Roma, 1929, ser. 6, vol. 10, pp. 656–664. [Min. Abstr., vol. 4, p. 522.]

[2] This locality is about 100 km. SE. of the phenakite locality in the Kisitwi Mountains described in 1906.

also $i(141)$ and some other undetermined forms in the striated zones [001], [100], and [$\bar{1}$01]. The crystal shows sub-parallel groupings and repetitions with a tendency to a sheaf-like aggregation of smaller individuals. Inequalities and crevices on the surfaces are partly filled with a thin coating of limonite.

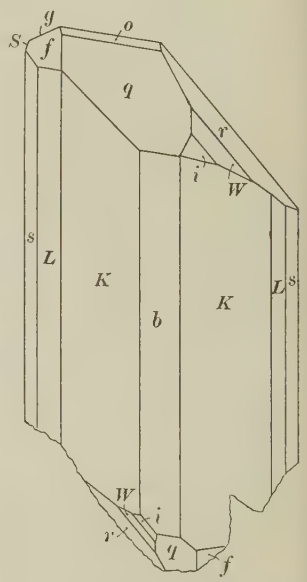


Fig. 1. Fig. 2.

Euclase from Tanganyika Territory (actual size).
Photograph of crystal and orthographic drawing on $b(010)$.

The common habit of euclase crystals from Brazil and the Urals is a flattened, almost lenticular, and heavily striated prism-zone, owing to the large development of $s(120)$ and $m(110)$ with small angles am 17° 40′ and as 32° 30′. On the present crystals $K(140)$ is the predominating prismatic form, and the stout prism has a greater thickness from back to front than in the direction of the b-axis. The form (140) was first recorded by E. Hussak [1] on a crystal from Bahia,

[1] E. Hussak, Min. Petr. Mitt. (Tschermak), 1892, vol. 12, p. 474.

Brazil, but, as pointed out by V. Dürrfeld,[1] he had in error interchanged the a and c axes, owing to the similarity of the angles in the zones [001] and [100] (see table on p. 620). His '$R(041)$' therefore becomes (140) and his '(140)' becomes (041). His letter R was allotted by Dana and Goldschmidt to the form (041); and (140) is now relettered K.

A small, clear and colourless, crystal was detached for goniometric measurement. This is 4 mm. long in the direction of the c-axis

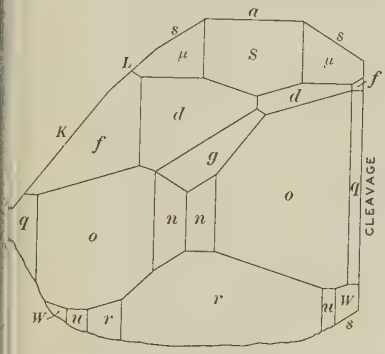


Fig. 3. Plan. ×18.

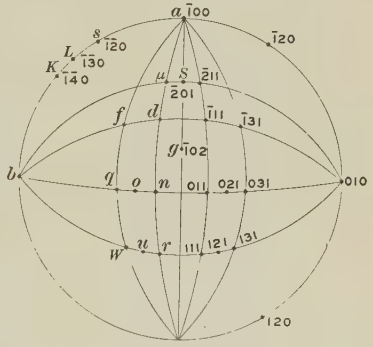


Fig. 4. Stereographic projection.

Euclase crystal from Tanganyika Territory.

and 2½ mm. across the prism-zone. It was grown in a corner between the larger crystals, and this no doubt accounts for its irregular development (fig. 3) as contrasted with the more regular growth of the larger crystals. Sixteen forms were determined, and the 28 faces (including two cleavages (010)) actually present are represented in figs. 3 and 4. The following table gives the normal angles for each of these forms (also for $i(141)$ present on the large crystal) to each of the three axial planes,[2] calculated from the axial ratios ($a:b:c$ = 0·32369 : 1 : 0·33324; $\beta = 79°\ 44'\ 4''$) which were determined with great elaboration by J. Schabus in 1852–4 on euclase crystals from Brazil.

[1] V. Dürrfeld, Zeits. Kryst. Min., 1910, vol. 47, p. 372. Dürrfeld had himself made the same error in his first description of euclase crystals from Epprechtstein, Bavaria.

[2] This method of giving a table of angles was used for schultenite, Min. Mag., 1926, vol. 21, pp. 151, 153. In the case of euclase $c(001)$ is very rarely developed and no prominent zones pass through its pole; but as shown in fig. 4 all the prominent zones pass through $a(100)$ and $b(010)$.

Forms of euclase and calculated angles to the axial planes.

Zones.	Forms.	Angle to a(100).	Angle to b(010).	Angle to c(001).
[001]	a(010)	—	90° 0′	79° 44′
	m(110) abs.	17° 40′	72 20	80 13
	s(120)	32 30	57 30	81 20
	L(130)	43 42	46 18	82 36
	K(140)	51 52	38 8	83 34
	b(010) cleav.	90 0	—	79 44
[010]	(101) abs.	39 10	90 0	40 34
	c(001) abs.	79 44	,,	—
	$g(\bar{1}02)$	108 53	,,	29 9
	$P(\bar{1}01)$ abs.	130 52	,,	51 8
	$S(\bar{2}01)$	152 23	,,	72 39
[100]	n(011)	80 15	71 51	18 9
	o(021)	81 26	56 44	33 15
	q(031)	82 42	45 28	44 32
[$\bar{1}$01]	r(111)	40 39	78 7	41 59
	u(121)	44 24	67 10	45 33
	W(131)	49 2	57 44	50 2
	i(141)	53 38	49 54	54 28
[101]	$d(\bar{1}11)$	129 23	75 51	52 31
	$f(\bar{1}31)$	121 19	52 55	60 20
[102]	$\mu(\bar{2}11)$	151 7	81 13	72 51

The measured angles were in close agreement with the calculated values. The following are given for the forms $K\,S\,W\,\mu$, since these, all with simple indices, are listed as doubtful in V. Goldschmidt's 'Atlas der Krystallformen' (1916, vol. 3) and they do not appear in Dana's 'System of Mineralogy' (6th edit., 1892).

		Measured.	Calculated.
$bK =$	$(0\bar{1}0):(\bar{1}40)$	38° 12′	38° 8′
$aS =$	$(\bar{1}00):(\bar{2}01)$	27 35	27 37
$bW =$	$(010):(131)$	57 43	57 44
aW	$(\bar{1}00):(131)$	131 7	130 58
$b\mu =$	$(010):(\bar{2}11)$	81 —	81 13
	$(0\bar{1}0):(\bar{2}\bar{1}1)$	82 —	
$a\mu =$	$(\bar{1}00):(\bar{2}11)$	28 47	28 53
	$(\bar{1}00):(\bar{2}\bar{1}1)$	28 52	

The faces of the form S and μ and of those in the prism-zone are striated parallel to their mutual intersections; those of d, f, and g are dull and minutely pitted; while the faces of other forms are bright and smooth.

Phenakite from South-West Africa.

A series of small specimens (B.M. 1932,1068–1071) labelled as coming from Klein Spitzkopje was acquired for the collection in 1932 from Mr. Willy Hirsch of München. The phenakite crystals on these specimens are of two distinct habits.

(1) Clear and colourless lenticular crystals, less than $\frac{1}{2}$ mm. to 4 mm. across, partly embedded in the surface of isolated crystals of

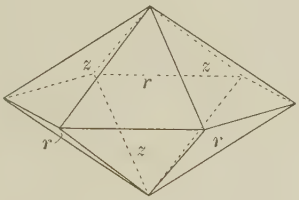


Fig. 5.

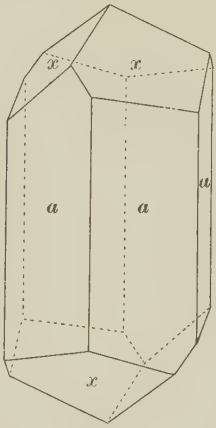


Fig. 6.

Two habits of phenakite crystals from South-West Africa.

microcline and smoky-quartz. They show an equal development of the two rhombohedra $r(100) = (10\bar{1}1)$ and $z(22\bar{1}) = (01\bar{1}1)$, and so have the appearance of a low doubly-terminated hexagonal pyramid (fig. 5), much like the bipyraminds of quartz only flatter. The crystals on quartz show these forms alone, but those on microcline show in addition a few other small faces $(a\,p\,d)$.[1] Only a few crystals are scattered over the surfaces of the quartz and microcline, but on the latter there are also a few shallow pits suggesting that other crystals of phenakite have become detached. The microcline is cream coloured with splashes of green and resembles other specimens from Klein Spitzkopje in the collection. The quartz crystal has some microcline attached at its base.

[1] Letters and indices as in Dana's System of Mineralogy, 6th edit., 1892.

(2) Prismatic crystals, up to 1 cm. long and ½ cm. across, either singly or confusedly aggregated in a small isolated group. They show a longitudinally striated and somewhat rounded or flattened hexagonal prism $a(10\bar{1}) = (11\bar{2}0)$ terminated by the rather steep rhombohedron $x(21\bar{1}) = (12\bar{3}2)$ skewly placed on the prism (fig. 6). Several of the crystals are doubly terminated. They are colourless but in part clouded by fissures and small black inclusions. Attached to them is some yellow clay, suggesting they were found in a cavity in the pegmatite.

These two habits of the crystals [1] are represented in figs. 5 and 6 and they afford a good illustration of how crystals of the same mineral may differ very markedly in appearance even when from the same locality. Phenakite in its mode of growth shows a striking contrast to quartz. In the latter the crystals grow with the *c*-axis standing out from the matrix, whereas in phenakite the *c*-axis lies on the matrix. The crystals of the lenticular habit are attached at their edge, while those of the prismatic habit are lying down. This orientation of the crystals was taken up at the commencement of their growth, and is probably a surface-tension effect.

The Klein (Little) Spitzkopje [2] is a granite hill forming a WSW. outlier, beyond the Gross (Great) Spitzkopje, of the granite of the Erongo Mountains in Damaraland. It is situated at latitude 21° 52′ S. and longitude 15° 3′ E., and 58 km. (36 miles) WNW. of Usakos on the railway from Walvis Bay. It has yielded the gem minerals beryl (aquamarine and heliodor), topaz, and tourmaline in some quantity, but there is some confusion in the statement of locality for this material. Many specimens labelled 'Namib Desert', 'Spitzkopje', 'Neu Schwaben', 'Usakos', and 'Rössing' are no doubt from Klein Spitzkopje. Gevers and Frommurze [3] in their account of the Erongo granite state that 'pegmatites . . . have been found only in a narrow zone along the western margin of the Little Spitzkopje, where they contain beryl, aquamarine, topaz and fluorite' (p. 49).

[1] The largest crystals of phenakite of these two habits in the British Museum collection are: a lenticular crystal 7 cm. wide and 3½ cm. in the direction of the *c*-axis from São Miguel de Piricicaba, Minas Geraes, Brazil; a prismatic crystal 18 cm. long and 3½ cm. across from Kragerø, Norway.

[2] Marked on the sketch-maps given by T. W. Gevers and H. F. Frommurze, Trans. Geol. Soc. South Africa, 1930, vol. 32 (for 1929), plates II and VI.

[3] T. W. Gevers and H. F. Frommurze, The geology of north-western Damaraland in South-West Africa. Ibid., pp. 31–55.

The excursion to South-West Africa organized by the International Geological Congress in 1929 and very successfully led by Dr. Gevers and Mr. Frommurze included a visit to the wonderful granite outcrops of the Erongo Mountains and the Gross Spitzkopje. A visit to the Klein Spitzkopje was unfortunately prevented by the coming dusk and the necessity of returning across the desert to Usakos. This I have regretted ever since.

Thirteenth list of new mineral names.[1]

By L. J. Spencer, M.A., Sc.D., F.R.S.
Keeper of Minerals in the British Museum of Natural History.

[Communicated June 7, 1934.]

Alkanasul. J. Westman, 1931. Bol. Minero Soc. Nac. Mineria, Santiago de Chile, vol. 43 (año 47), p. 433; Zeits. Prakt. Geol., 1932, vol. 40, p. 110. Hydrous basic sulphate of aluminium, potassium, and sodium, $K_2SO_4.Na_2SO_4.2Al_2(SO_4)_3.6Al(OH)_3.6H_2O$, yellowish-white to bluish-grey, massive, occurring in large amount near Salamanca, Chile. Named from the chemical composition. [Evidently identical with natroalunite.] [M.A. **5**–200.]

Alleghanyite. C. S. Ross and P. F. Kerr, 1932. Amer. Min., vol. 17, p. 7. Manganese silicate, $5MnO.2SiO_2$, as pink orthorhombic grains, considered to be distinct from tephroite [$2MnO.SiO_2$]. Named from the locality, Alleghany County, North Carolina. [M.A. **5**–50.]

Alumo-chalcosiderite. A. Jahn and E. Gruner, 1933. Mitt. Vogtländ. Gesell. Naturfor., vol. 1, no. 8, p. 19 (Alumo-Chalkosiderit). A variety of chalcosiderite containing some alumina (Al_2O_3 10·45 %) replacing ferric oxide. [M.A. **5**–391.]

Amarillite. H. Ungemach, 1933. Compt. Rend. Acad. Sci. Paris, vol. 197, p. 1133; Bull. Soc. Franç. Min., [1934], vol. 56 (for 1933), p. 303. Hydrated sulphate of sodium and ferric iron $NaFe(SO_4)_2.6H_2O$, as yellow monoclinic crystals from Tierra Amarilla, Chile. Named from the locality. [M.A. **5**–390.]

[1] Previous lists of this series have been given every three years at the ends of vols. 11–22 (1897–1931) of this Magazine. The 1,506 names in the first ten lists are included in one alphabetical arrangement in the General Index (1926) to vols. 11–20 (1895–1925). References to 'Mineralogical Abstracts' are given in the form [M.A. 5–200].

'A compilation of gem names' by Gilbert Hart (Rocks and Minerals, Peekskill, New York, 1927–31, vols. 2–6) is an extension of the earlier list of W. T. Schaller (1918; 8th List) and contains many trivial, local, and trade names which are not included in the present lists.

Anhydrokaolin. R. Schwarz and G. Trageser, 1932. Chemie der Erde, vol. 7, p. 583 (Anhydrokaolin). Artificially dehydrated kaolin which passes with change in volume to metakaolin (10th List). [M.A. **5**–361.]

Antiglaucophane. W. N. Lodochnikov, 1933. Problems of Soviet Geology, vol. 2, p. 132 (антиглаукофан), p. 148 (antiglaucophane). Like glaucophane but differing (*ἀντι-*) somewhat in its optical characters. Compare Pseudoglaucophane (11th List).

Antimonpyrochlore. F. Machatschki, 1932. Chemie der Erde, vol. 7, pp. 67, 75 (Antimonpyrochlor). The pyrochlore-romeite group of minerals with the same type of cubic structure and the general formula $X_2Z_2(O,OH,F)_7$, where X = Na, Ca, Ce, &c., and Z = Nb, Ta, Ti, Sb, includes the chemical varieties niobpyrochlore (pyrochlore proper), tantalpyrochlore (microlite), niobtantalpyrochlore (neotantalite), antimonpyrochlore (romeite, atopite, schneebergite, weslienite), Bleiantimonpyrochlor (monimolite ?), titanantimonpyrochlore (mauzeliite, lewisite), and a hypothetical titanpyrochlore. [M.A. **5**–185.]

Ardealite. J. Schadler, 1931. *In* F. Halla, Zeits. Krist., vol. 80, p. 349; J. Schadler, Centr. Min., Abt. A, 1932, p. 40 (Ardealit). Hydrated double salt of calcium sulphate and acid phosphate, $CaHPO_4.CaSO_4.4H_2O$, isomorphous with brushite ($CaHPO_4.2H_2O$) and gypsum ($CaSO_4.2H_2O$), but not a mechanical mixture of these minerals; occurring in phosphate deposits in a cave in Transylvania, the old Romanian name for which is Ardeal. Named from the locality. [M.A. **5**–49.]

Ashcroftine. M. H. Hey and F. A. Bannister, 1932. Nature, London, vol. 130, p. 858. Min. Mag., 1933, vol. 23, p. 305. A zeolite of the composition $NaKCaAl_4Si_5O_{18}.8H_2O$, previously described as kalithomsonite (10th List), but shown to be tetragonal and to have no relation to thomsonite. From Greenland. Named after Mr. Fredrick Noel Ashcroft, of London.

Ashtonite. E. Poitevin, 1932. Amer. Min., vol. 17, p. 120. A zeolite related to ptilolite, but with 2RO instead of 1RO, the formula being $2(Ca,Na_2)O.Al_2O_3.9SiO_2.5H_2O$. As radiating masses from British Columbia. Named after the Honourable Wesley Ashton Gordon, Minister of Mines for Canada. [M.A. **5**–50.]

Balkhashite. S. V. Kumpan, Bull. Geol. Prosp. Service U.S.S.R., 1931, vol. 50, no. 7, p. 95 (балхашит), p. 100 (balkhashite). G. L. Stadnikov and Z. Vosdshinskaya, Brennstoff-Chemie, 1930, vol. 11, p. 414; G. L. Stadnikov, ibid., 1933, vol. 14, p. 227 (Balchaschit). A rubbery bitumen (elaterite) similar to coorongite formed by algae in lake Balkhash (Балхаш), Siberia.

Barium-anorthite. S. R. Nockolds and E. G. Zies, 1933. Min. Mag., vol. 23, p. 454 (barium anorthite). A plagioclase felspar containing BaO 5·5 %, from Broken Hill, New South Wales.

Barium-muscovite. L. H. Bauer and H. Berman, 1933. Amer. Min., vol. 18, p. 30. A variety of muscovite containing barium (BaO 9·89 %). Synonym of oellacherite (J. D. Dana, 1867). [M.A. **5**–284.]

Börzsönyite. F. Papp, 1933. Földtani Közlöny, Budapest, vol. 62 (for 1932), p. 61 (Börzsönyit). Suggested as an alternative for the names wehrlite (J. J. N. Huot, 1841) and pilsenite (A. Kenngott, 1853) for an incompletely determined bismuth telluride [probably identical with tetradymite] from Börzsöny = Deutsch-Pilsen, comitat Hont, Hungary; because the name wehrlite (F. Kobell, 1838) is also applied to a peridotite rock [earlier thought to be the mineral ilvaite], and the German name Deutsch-Pilsen for the locality is now not recognized in Hungary.

Boydite. (W. F. Foshag, Amer. Min., 1931, vol. 16, p. 338.) Local name for a borate mineral in California, since identified as probertite (12th List). [M.A. **5**–52.]

Braggite. F. A. Bannister, 1932. Min. Mag., vol. 23, p. 198. Sulphide of platinum, palladium, and nickel, (Pt,Pd,Ni)S, tetragonal, as minute grains in the concentrates of the Bushveld norite, Transvaal. Named after Sir William Henry Bragg and Professor William Lawrence Bragg, as being the first new mineral to be discovered by X-ray methods.

Brickerite. Barrande-Hesse, 1932. *In* F. Ahlfeld, Neues Jahrb. Min., Abt. A, 1932, Beil.-Bd. 66, pp. 42, 44 (Brickerit). Arsenate of zinc and calcium as white radially fibrous crusts from Bolivia. [M.A. **5**–200.]

Bultfonteinite. J. Parry, A. F. Williams, and F. E. Wright, 1932. Min. Mag., vol. 23, p. 145. Hydrous calcium silicate and

fluoride, $2Ca(OH,F)_2.SiO_2$ or $2Ca(OH)_2.2SiO_2.Ca(OH)_2.CaF_2$. Pink spherules of radiating triclinic needles from the Bultfontein diamond mine, Kimberley, South Africa. Named from the locality. *See* Dutoitspanite.

Caesium-biotite. F. L. Hess and J. J. Fahey, 1932. Amer. Min., vol. 17, p. 173 (Caesium biotite). A variety of biotite from South Dakota containing Cs_2O 3·14 %. [M.A. **5**–192.]

Chrome-beidellite. D. P. Serdyuchenko, 1933. Zap. Ross. Min. Obshch. (Mém. Soc. Russe Min.), ser. 2, vol. 62, p. 380 (хромовый байделит), p. 391 (chrome-beidellite). A variety of beidellite containing chromium (Cr_2O_3 5·02 %) and grading to wolchonskoite (volkonskoite), $(Cr,Fe^{III},Al)_2O_3.3SiO_2.nH_2O$; from northern Caucasus. [M.A. **5**–486.]

Chrome-nontronite. D. P. Serdyuchenko, 1933. Zap. Ross. Min. Obshch. (Mém. Soc. Russe Min.), ser. 2, vol. 62, p. 376 (хромовый нонтронит), p. 390 (chrome-nontronite). A variety of nontronite (chloropal) containing chromium and grading to wolchonskoite (volkonskoite), $(Cr,Fe^{III},Al)_2O_3.3SiO_2.nH_2O$. [M.A. **5**–486.]

Chromojadeite. A. Lacroix, 1930. Bull. Soc. Franç. Min., vol. 53, p. 226 (Chromojadéite). Synonym of tawmawite (A. W. G. Bleeck, 1907; 5th List) for a chromiferous jadeite from Tawmaw, Burma. [M.A. **5**–71.]

Clinoguarinite. G. Cesàro, 1932. Mém. (8°) Acad. Roy. Belgique, Cl. Sci., vol. 12, fasc. 3, p. 18. The optical orientation of guarinite points to two varieties, orthorhombic and monoclinic, which are termed orthoguarinite and clinoguarinite respectively. They occur intergrown in the same crystal and the former is no doubt a minutely twinned form of the latter, as in orthoclase and microcline. [M.A. **5**–426.]

Colusite. A name used locally for tin-bearing ores at Butte, Montana. At first thought to be a stanniferous tennantite (H. Schneiderhöhn and P. Ramdohr, Lehrbuch der Erzmikroskopie, 1931, vol. 2, p. 433. R. E. Landon, Amer. Min., 1932, vol. 17, p. 575; 1933, vol. 18, p. 114), but later described (R. E. Landon and A. H. Mogilnor, Amer. Min., 1933, vol. 18, p. 528. W. H. Zachariasen, ibid., p. 534) as a mineral of the zinc-blende group with the

composition $(Cu,Fe,Mo,Sn,Zn)_4(S,As,Te,Sb)_{3-4}$. Named from the Colusa claim, which was one of the earliest in the Butte district. [M.A. **5**–388.]

Corvusite. E. P. Henderson and F. L. Hess, 1933. Amer. Min., vol. 18, p. 199. Hydrated vanadic pentoxide and dioxide, $V_2O_4.6V_2O_5.xH_2O$, as bluish-black compact material in sandstone from Utah. Named on account of the colour from the Latin corvus, a raven. [M.A. **5**–293.]

Cuprosklodowskite. H. Buttgenbach, 1933. Ann. Soc. Géol. Belgique, vol. 56, Bull. p. B 331 (cuprosklodovskite). Hydrous silicate and uranate of copper as yellowish-green orthorhombic needles with the characters of sklodowskite [$MgO.2UO_3.2SiO_2.7H_2O$; 10th List] but with CuO in place of MgO; from Katanga, Belgian Congo. [M.A. **5**–389.]

Devitrite. G. W. Morey and N. L. Bowen, 1931. The Glass Industry, New York, vol. 12, p. 133; Journ. Soc. Glass Technology, Sheffield, 1931, vol. 15, abstracts p. A 133. Orthorhombic $Na_2O.3CaO.6SiO_2$, common in devitrified commercial glasses. Perhaps the same as reaumerite (6th List). [M.A. **3**–167.]

Duparcite. S. E. Nicolet, 1932. Schweiz. Min. Petr. Mitt., vol. 12, p. 543 (Duparcite). E. Brandenberger, ibid., p. 545 (Duparcit). Radiating groups of long prisms in hornstone from Morocco with characters very near those of idocrase and genevite (11th List). Named after Professor Louis Duparc (1866–1932), of Genève. [M.A. **5**–292.]

Dutoitspanite. A. F. Williams, 1932. The genesis of the diamond, London, vol. 1, pp. 171, 172. Synonym of bultfonteinite (q.v.). Named from the Dutoitspan diamond mine, Kimberley, South Africa, one of the localities of the mineral. [M.A. **5**–97.]

Eicotourmaline. W. N. Lodochnikov, 1933. Problems of Soviet Geology, vol. 2, p. 132 (эйкотурмалин), p. 148 (eicotourmaline). Like (εἰκός) tourmaline, but optically biaxial and containing no boron.

Enalite. K. Kimura and Y. Miyake, 1932. Journ. Chem. Soc. Japan, vol. 53, p. 93 (Japanese; English title on wrapper); abstract

in Amer. Min., 1933, vol. 18, p. 223. Hydrous silicate of thorium and uranium, $(Th,U)O_2.nSiO_2.2H_2O$, tetragonal, a variety of uranothorite, as orange-yellow grains with monazite in sands in the Ena district, Gifu prefecture, Japan. Named from the locality. [M.A. **5**–293.]

Esaidrite. (C. Andreatta, Atti (Rend.) R. Accad. Sci. Lincei, Roma, 1932, ser. 6, vol. 16, p. 62.) Italian form of Hexahydrite ($MgSO_4.6H_2O$, of R. A. A. Johnston, 1911; 6th List).

Feranthophyllite. A. N. Winchell, 1933. Optical mineralogy, part 2, 3rd edit., p. 241. A contraction of Ferroanthophyllite (9th List).

Ferroamesite. G. L. Dschang, 1931. Chem. Erde, vol. 6, p. 427 (Ferroamesit). A hypothetical molecule $H_4Fe_2Al_2SiO_9$ (corresponding with amesite $H_4Mg_2Al_2SiO_9$) to explain the composition of the chlorites. [M.A. **5**–39.]

Ferrotremolite. A. N. Winchell, 1932. Amer. Min., vol. 17, pp. 114, 472; Optical mineralogy, part 2, 3rd edit., 1933, p. 245. The end-member $H_2Ca_2Fe_5Si_8O_{24}$ of the tremolite-actinolite series, actinolite being really an intermediate member. [M.A. **5**–216.]

Ferruccite. G. Carobbi, 1933. Periodico Min. Roma, vol. 4, p. 410. Sodium fluoborate, $NaBF_4$, occurring as minute orthorhombic crystals in mixed fumarolic sublimations on Vesuvius. Named after Prof. Ferruccio Zambonini (1880–1932), of Napoli. [M.A. **5**–390.]

Galaxite. C. S. Ross and P. F. Kerr, 1932. Amer. Min., vol. 17, p. 15. Manganese aluminate, $MnAl_2O_4$, belonging to the spinel group, as black grains in manganese-ore from North Carolina. Named from the neighbouring town of Galax in Virginia, which itself is named from the local plant galax, milk-wort. Compare galactite; scarcely an appropriate name for a black mineral. [M.A. **5**–51.]

Ginorite. G. D'Achiardi, 1934. Periodico Min. Roma, vol. 5, p. 22 (ginorite). Hydrous borate of calcium, $H_{12}Ca_4B_{14}O_{29}.2H_2O$, as a compact white mass of minute monoclinic crystals from Tuscany. Named after Prince Piero Ginori Conti, of Firenze (Florence). [M.A. **5**–484.]

Girnarite. K. K. Mathur and A. G. Jhingran, 1931. Quart. Journ. Geol. Mining Metall. Soc. India, vol. 3, p. 100. An amphibole of the hastingsite group in nepheline-syenite at Mount Girnar, Kathiawar, India. Named from the locality. [M.A. **5**–391.]

Glaucocerinite. E. Dittler and R. Koechlin, 1932. Centr. Min., Abt. A, 1932, p. 13 (Glaukokerinit). A hydrous ultra-basic sulphate of zinc, aluminium, and copper, $Zn_{13}Al_8Cu_7(SO_4)_2O_{30}.34H_2O$, as sky-blue warty masses of soft waxy material, from Laurion, Greece. Named from γλαυκός, blue, and κήρινος, waxy. [M.A. **5**–49.]

Graebeite. A. Treibs and H. Steinmetz, 1933. Liebigs Ann. Chem., vol. 506, p. 171 (Graebeït). Brick-red smears in crevices in shale from a coal mine in Saxony, possessing dyeing properties, and identified as a mixture (graebeite a and graebeite b) of polyhydroxyanthraquinones. Named after Carl Graebe (1841–1927), formerly Professor of Chemistry at Genève, who did much work on the anthracene series. [Cf. Hoelite, 10th List.] [M.A. **5**–391.]

Gränzerite. [J. E. Hibsch, MS.] R. Koechlin, Min. Taschenbuch Wiener Min. Gesell., 2nd edit., 1928, p. 27; Centr. Min., Abt. A, 1933, p. 203. J. E. Hibsch, Min. Böhm. Mittelgeb., 1934, p. 109. Synonym of sanidine. A druse mineral in basalt from Eulenberg, Bohemia. Named after Dr. Josef Gränzer, of Reichenberg, Bohemia. [M.A. **5**–296, 482.]

Gumucionite. R. Herzenberg, 1932. Revista Minera, Soc. Argentina Mineria y Geol., vol. 4, p. 65 (gumucionita); Centr. Min., Abt. A, 1933, p. 77 (Gumucionit). A raspberry-red botryoidal variety of blende containing some arsenic (As 0·64 %) from Bolivia. Named after the mining engineer Julio F. Gumucio, by whom it was found. [M.A. **5**–199, **5**–295.]

Harbortite. F. Brandt, 1932. Chemie der Erde, vol. 7, p. 392 (Harbortit). Hydrous aluminium (and iron) phosphate, $6Al_2O_3.4P_2O_5.17H_2O$, as white to brown spherulites in phosphatized laterite from Brazil. Named after Prof. Erich Harbort (1879–1929), of Berlin-Charlottenburg. [M.A. **5**–201.]

Huanite. *See* Juanite.

Hydrocalumite. C. E. Tilley, 1934. Min. Mag., 1934, vol. 23, p. 607. Hydrous calcium aluminate, $4CaO.Al_2O_3.12H_2O$, monoclinic,

in a chalk-dolerite contact-rock at Scawt Hill, Co. Antrim. Named from the chemical composition.

Hydroromeite. G. Natta and M. Baccaredda, 1933. Zeits. Krist., vol. 85, pp. 271, 273 (Idroromeite), p. 295 (Hydroromeit). Calcium-bearing antimony-ochres, $CaO.Sb_2O_5.3H_2O$ and $3CaO.2Sb_2O_5 8H_2O$, from Spain, shown by X-ray analysis to have the same cubic structure as romeite ($2CaO.Sb_2O_5$). [M.A. **5**–294.]

Idroromeite. *See* Hydroromeite.

Igalikite. O. B. Bøggild, 1933. Meddelelser om Grønland, vol. 92, no. 9. Approximate composition $NaKAl_4Si_4O_{15}.2H_2O$, as a polysynthetic aggregate of minute scales. From near Igaliko, south Greenland. Named from the locality. [M.A. **5**–484.]

Iso-orthoclase, Isorthoclase. T. F. W. Barth, Amer. Min., 1933, vol. 18, p. 478 (iso-orthoclase); A. N. Winchell, Elements of optical mineralogy, part 2, 2nd edit., 1927, p. 322 (Isorthoclase). Variants of the French Isorthose (L. Duparc, 1904; 4th List). [M.A. **5**–438.]

Jäneckeite. L. T. Brownmiller and R. H. Bogue, Amer. Journ. Sci., 1930, ser. 5, vol. 20, p. 251 (Janeckite). F. Krauss and G. Jörns, Zement, Charlottenburg, 1931, vol. 20, p. 341 (Jäneckeit). O. F. Honus, Chimie et Industrie, Paris, 1931, vol. 26, p. 1011 (Jaeneckéite). $8CaO.Al_2O_3.2SiO_2$, as a constituent of Portland cement clinkers. Named after E. Jänecke, who first distinguished it from alite (2nd List). [M.A. **4**–366.]

Janite. S. J. Thugutt, 1933. Arch. Min. Soc. Sci. Varsovie, vol. 9, p. 93 (janicie), p. 97 (janite). Hydrated silicate of Fe_2O_3,Al,Mg,Ca, &c., related to chloropal or celadonite, occurring in an altered glassy basalt from the Janowa valley, Volhynia, Poland. Named from the locality. [M.A. **5**–485.]

Jarlite. R. Bøgvad, 1933. Meddelelser om Grønland, vol. 92, no. 8, p. 3 (Jarlite). A fluoride, $NaSr_3Al_3F_{16}$, as small colourless monoclinic crystals, from the Greenland cryolite quarry. Named after Mr. C. F. Jarl, of Øresunds Chemiske Fabriker. *See* Metajarlite. [M.A. **5**–387.]

Johannsenite. W. T. Schaller, 1932. Amer. Min., vol. 17, p. 575; 1933, vol. 18, p. 113. N. L. Bowen, J. F. Schairer, and

E. Posnjak, Amer. Journ. Sci., 1933, ser. 5, vol. 26, p. 274. A monoclinic pyroxene $MnCaSi_2O_6$, isomorphous with diopside and dimorphous with bustamite. Named after Prof. Albert Johannsen, of Chicago.

Juanite. E. S. Larsen and E. A. Goranson, 1932. Amer. Min., vol. 17, pp. 343. 349, 354 (juanite, pronounced huanite). $10CaO.4MgO.Al_2O_3.11SiO_2.4H_2O$, white fibrous sheaves, perhaps orthorhombic, occurring as an alteration product of melilite. Named after the San Juan Mountains, Colorado. [M.A. **5**–146.]

Kiscellite. L. Zechmeister, G. Tóth, and A. Koch, 1934. Centr. Min., Abt. A, 1934, p. 60 (Kiscellit). A brown amber-like resin containing sulphur in place of oxygen, from the Kisczelli tályag (Hung.) = Kleinzeller Tegel (Germ.) beds of Oligocene age at Budapest. Named from the geological horizon, which is named from the locality Kis-Czell near Budapest. [M.A. **5**–485.]

Knollite. [A. Pelikan, MS.] R. Koechlin, Centr. Min., Abt. A, 1933, p. 204. Synonym of zeophyllite. Named after Mr. — Knoll. [M.A. **5**. 296.]

Kolbeckine. R. Herzenberg, 1932. Revista Minera, Soc. Argentina Mineria y Geol., vol. 4, p. 33 (Kolbeckina); Centr. Min., Abt. A, 1932, p. 354 (Kolbeckin). Tin sulphide, Sn_2S_3, as minute black scales from Bolivia. Evidently named after Prof. Friedrich Kolbeck, of the Mining Academy, Freiberg, Saxony. [Not the kolbeckite of F. Edelmann, 1926; 11th List.] [M.A. **5**–199.]

Lapparentite. H. Ungemach, 1933. Compt. Rend. Acad. Sci. Paris, vol. 197, p. 1133; Bull. Soc. Franç. Min., [1934], vol. 56 (for 1933), p. 303. Hydrated basic sulphate of aluminium, $Al_2O_3.2SO_3.10H_2O$, as monoclinic crystals resembling gypsum in appearance. From Chile. Named after Albert Auguste de Lapparent (1839–1908), of Paris. [M.A. **5**-390.]

Legrandite. J. Drugman and M. H. Hey, 1932. Min. Mag., vol. 23, p. 175. Hydrous zinc arsenate, approximating to $Zn_3As_2O_8.3H_2O$, but more exactly $Zn_{14}(AsO_4)_9OH.12H_2O$. Bundles of yellow acicular monoclinic crystals with blende from Mexico. Named after the late Mr. — Legrand, a Belgian mining engineer.

Letovicite. J. Sekanina, 1932. Zeits. Krist., vol. 83, p. 117 (Letovicit). Triammonium sulphate $H(NH_4)_3(SO_4)_2$ as pseudo-hexagonal scales from the decomposition of pyrite in coal at Letovice, Moravia. Named from the locality. [M.A. **5**–145.]

Leucoglaucite. H. Ungemach, 1933. Compt. Rend. Acad. Sci. Paris, vol. 197, p. 1134; Bull. Soc. Franç. Min., [1934], vol. 56 (for 1933), p. 303. Hydrated ferric sulphate, $Fe_2O_3.4SO_3.5H_2O$, as pale greenish-blue hexagonal crystals, from Chile. Named from the colour. *λευκός*, white, and *γλαυκός*, greenish-blue. [M.A. **5**–390.]

Leucophosphite. E. S. Simpson, 1932. Journ. Roy. Soc. W. Australia, vol. 18, p. 71. Hydrous phosphate of potassium, iron, and aluminium, perhaps $K_2(Fe,Al)_7(OH)_{11}(PO_4)_4.6H_2O$, as white chalky masses from Western Australia. Named from *λευκός*, white, and *φωσφόρος*. [M.A. **5**–148.]

Lusakite. A. C. Skerl and F. A. Bannister, 1934. Min. Mag., vol. 23, p. 598. Silicate of aluminium, cobalt (CoO 8·48 %), iron, magnesium, and nickel, $H_2O.4R^{II}O.9(Al,Fe)_2O_3.8SiO_2$, as deep-blue orthorhombic crystals, from near Lusaka, Northern Rhodesia. A cobaltiferous variety of staurolite. Named after the locality, the new capital of Northern Rhodesia.

Madisonite. R. S. McCaffery and J. F. Oesterle, 1924. Year Book Amer. Iron & Steel Inst., 1924, p. 286. $2CaO.2MgO.Al_2O_3.3SiO_2$(?) as a constituent of iron blast furnace slags. Evidently named after Madison, Wisconsin, where the authors are professors of metallurgy.

Maganthophyllite. A. N. Winchell, 1933. Optical mineralogy, part 2, 3rd edit., p. 241. A contraction of Magnesioanthophyllite (9th List).

Magnesiosussexite. J. W. Gruner, 1932. Amer. Min., vol. 17, p. 509. Hydrous borate of magnesium and manganese, $2(Mg,Mn)O.B_2O_3.H_2O$, intermediate between camsellite and sussexite, as fibrous veinlets in iron ore from Michigan. [Sussexite also contains a large proportion of magnesia, and camsellite still more.] [M.A. **5**–201.]

Mangano-anthophyllite. C. S. Ross and P. F. Kerr, 1932. Amer. Min., vol. 17, pp. 4, 17. A variety of anthophyllite occurring as a pink alteration product of rhodonite. [M.A. **5**–51.]

Mangan-muscovite. P. Eskola, 1914. Bull. Comm. Géol. Finlande, vol. 8, no. 40, p. 37 (manganese-muscovite). A compact, fine scaly, manganiferous (MnO 2·30 %) variety of muscovite of a deep violet colour, from Kimito, Finland. Bull. Soc. Franç. Min., 1933, vol. 56, p. 188 (Manganmuscovite).

Melosark. [A. Breithaupt, 1841, MS.] R. Koechlin, Min. Taschenbuch Wiener Min. Gesell., 2nd edit., 1928, p. 41; Centr. Min., Abt. A, 1933, p. 203 (Melosark). Synonym of melopsite. Named from *μῆλον*, apple, and *σάρξ*, flesh (*ὄψον*, meat). [M.A. **5**–296.]

Metacalciowardite. H. G. Clinton, 1929. Amer. Min., vol. 14, pp. 435, 436. An undescribed mineral, presumably a calciferous variety of wardite (1st List), occurring with other aluminium phosphates at Manhattan, Nevada. [M.A. **4**–296.]

Meta-chamosite. H. Jung, 1932. Chem. Erde, vol. 7, p. 598 (Meta-Chamosit). Artificially dehydrated chamosite. [M.A. **5**–284.]

Meta-jarlite. R. Bøgvad, 1933. Meddelelser om Grønland, vol. 92, no. 8, p. 7 (Meta-Jarlite). A fluoride, $NaSr_3Al_3F_{16}$, as small grey crystals enclosed in chiolite, from the Greenland cryolite quarry. Supposed to differ from jarlite (q.v.) in its optical characters. [M.A. **5**–388.]

Meta-thuringite. H. Jung, 1932. Chem. Erde, vol. 7, p. 596 (Meta-Thuringit). Artificially dehydrated thuringite. [M.A. **5**–284.]

Microantigorite. W. N. Lodochnikov, 1933. Problems of Soviet Geology, vol. 2, p. 121 (микроантигорит), p. 145 (microantigorite). A minutely crystalline antigorite.

Minyulite. E. S. Simpson and C. R. LeMesurier, 1933. Journ. Roy. Soc. Western Australia, vol. 19, p. 13. Hydrated basic phosphate of aluminium and potassium, $KAl_2(OH,F)(PO_4)_2.3\frac{1}{2}H_2O$, as radiating groups of white orthorhombic fibres, from Minyulo Well, Dandaragan, Western Australia. Named from the locality. [M.A. **5**–293.]

Mohavite. W. T. Schaller, 1928. Amer. Min., vol. 13, p. 453. Synonym of tincalconite (C. U. Shephard, 1878) or 'octahedral borax', rhombohedral $Na_2B_4O_7.5H_2O$. Named from the Mohave desert, California. [M.A. **4**–246.]

Mourmanite. French spelling of Murmanite (10th List). [M.A. **5**–198.]

Naujakasite. O. B. Bøggild, 1933. Meddelelser om Grønland. vol. 92, no. 9. Approximate composition $HNa_3Al_2Si_4O_{13}$, as micaceous scales, from Naujakasik, south Greenland. Named from the locality. [M.A. **5**–484.]

Nephritoid. G. P. Barsanov, 1933. Trav. Inst. Lomonossoff, Acad. Sci. Leningrad, no. 2, p. 5 (нефритоид, nephritoïde). A variety of serpentine similar to bowenite [Not the nephritoid of J. Fromme, 1909; 5th List.]

Neuquenite. A. W. Allen, 1932. Engin. & Mining Journ. New York, vol. 133, p. 566. A variety of asphalt from Neuquen Territory, Argentina, differing from rafaelite [11th List]. Named from the locality.

Orthoguarinite. G. Cesàro, 1932. *See* Clinoguarinite.

Oxoferrite. R. Schenck and T. Dingmann, 1927. Zeits. Anorg. Chem., vol. 166, p. 140 (Oxoferrit). Metallic iron with some FeO in solid solution.

Oxyhornblende. A. N. Winchell, 1932. Amer. Min., vol. 17, pp. 114, 472; Optical mineralogy, part 2, 3rd edit., 1933, p. 252. 'Basaltic hornblende' in which the ferrous oxide has been oxidized to ferric. [M.A. **5**–216.]

Paracoquimbite. H. Ungemach, 1933. Compt. Rend. Acad. Sci. Paris, vol. 197, p. 1133; Bull. Soc. Franç. Min., [1934], vol. 56 (for 1933), p. 303. Violet rhombohedral crystals dimorphous with the hexagonal coquimbite, $Fe_2(SO_4)_3.9H_2O$, the two often grown in parallel position. From Chile. [M.A. **5**–390.]

Parryite. A. F. Williams, 1932. The genesis of the diamond, London, vol. 1, p. 172. An undescribed hydrous calcium silicate from the diamond mines at Kimberley, South Africa. Named after John Parry (1863–1931), chemist to the De Beers Consolidated Mines at Kimberley. [M.A. **5**–97.]

Phosphoro-orthite. F. Machatschki; 1931. Centr. Min., Abt. A, 1930, p. 347 (Phosphoroorthit, Phosphorerdenepidot). A variety of orthite in which some phosphorus takes the place of silicon. Synonym of nagatelite (12th List). [M.A. **5**–52.]

Porcelainite. A. L. Roussin, 1932. *In* W. H. Taylor, Journ. Soc. Glass Techn. Sheffield, 1932, vol. 16, p. 118. Later replaced by Porzite (q.v.). Porcelainite has long been used as a trade-name for certain kinds of white stoneware. Not the porcellanite (= porcelain-jasper) of J. T. A. Peithner, 1794.

Portlandite. C. E. Tilley, 1933. Min. Mag., vol. 23, p. 419. Calcium hydroxide, $Ca(OH)_2$, as hexagonal plates in a chalk-dolerite contact-rock at Scawt Hill, Co. Antrim. So named because crystals of this substance had been earlier observed in Portland cement. (Portland cement was named in 1824 because of its resemblance in colour to the oolitic limestone—Portland stone—from the Isle of Portland in Dorsetshire.)

Porzite. A. J. Bradley and A. L. Roussin, 1932. Trans. Ceramic Soc. Stoke-on-Trent, vol. 31, p. 426. A fibrous constituent of porcelain, belonging to the fibrolite-mullite series. The X-ray pattern shows a closer relation to that of 'pink mullite' than to that of 'grey mullite'. E. Posnjak and J. W. Greig (Journ. Amer. Ceramic Soc., 1933, vol. 16, p. 579) suggest it is identical with mullite. [M.A. **5**–323, 473.]

Potash-anorthoclase. K. Kimizuka, 1932. Japanese Journ. Geol. Geogr., vol. 9, p. 225. A triclinic felspar of the composition $Or_{66}Ab_{31}An_3$. [M.A. **5**–363.]

Prokaolin. R. Schwarz and G. Trageser, 1932. Chemie der Erde, vol. 7, p. 566 (Prokaolin). Precipitated amorphous $Al_2O_3.2SiO_2.nH_2O$, from which kaolin can be prepared artificially. [M.A. **5**–361.]

Pseudo-edingtonite. M. H. Hey, 1934. Min. Mag., vol. 23, pp. 491, 493. Potassium and sodium pseudo-edingtonites are base-exchange products of edingtonite with a crystal-structure different from that of edingtonite.

Pseudosillimanite. J. de Lapparent, 1920. Compt. Rend. Congrès Soc. Sav. Sci. Paris, 1920, p. 77 ; Bull. Serv. Carte Géol. Alsace Lorraine, Strasbourg, 1923, vol. 1, p. 54 (pseudosillimanite). An undetermined mineral occurring as minute prisms resembling fibrolite (sillimanite) in a metamorphic phthanite containing radiolaria from Alsace. A similar mineral is recorded from Tierra del

Fuego by E. H. Kranck, Acta Geogr. Helsingfors, 1932, vol. 4, no. 2, p. 146 (pseudosillimannite), p. 150 (pseudo-sillimannite).

Radiofluorite. F. L. Hess, 1931. Amer. Journ. Sci., ser. 5, vol. 22, p. 220; 1933, ser. 5, vol. 25, p. 426. Strongly radioactive fluorite, suggested to be $(Ca,Ra)F_2$. W. L. Brown (Univ. Toronto Studies, Geol. Ser., 1932, no. 32, p. 56) shows that the supposed radioactive effect on a photographic plate is due to phosphorescence. [M.A. **5**–52, 235, 330.]

Rilandite. E. P. Henderson and F. L. Hess, 1933. Amer. Min., vol. 18, p. 202. Hydrous basic silicate of chromium and aluminium (Cr_2O_3 47·59 %), as brownish-black pitch-like masses in sandstone from Colorado. Named after Mr. J. L. Riland, of Meeker, Colorado. [M.A. **5**–293.]

Rosickyite. J. Sekanina, 1931. Zeits. Krist., vol. 80, p. 174 (Rosickýit). Monoclinic γ-sulphur as minute crystals from the decomposition of pyrite nodules in Cretaceous clay in Moravia. Named after Prof. Vojtěck Rosický, of Brno (= Brünn), Moravia. [M.A. **5**–49.]

Safranite. Gemmologist, London, 1933, vol. 2, pp. 346, 375; 1933, vol. 3, p. 61; 1934, vol. 3, p. 328. Deutsche Goldschmiede-Zeitung, 1933, vol. 36, p. 207. Neues Jahrb. Min., Abt. A, Ref. I, 1934, p. 154. Safranite or Topaz-safranite, trade-names for yellow gem quartz, sometimes sold as topaz. Apparently named from safran, French for saffron.

Saleite. J. Thoreau and J. F. Vaes, 1932. Bull. Soc. Belge Géol., vol. 42, p. 96 (saléite). Hydrous phosphate of uranium and magnesium, $MgO.2UO_3.P_2O_5.8H_2O$, as yellow square plates (orthorhombic) from Katanga. Named after Prof. Achille Salée, of Louvain, Belgium. [M.A. **5**–292.]

Sanbornite. A. F. Rogers, 1932. Amer. Min., vol. 17, pp. 117, 161. Barium metadisilicate, $BaSi_2O_5$, as white pearly cleavages, triclinic, from California. Named after Mr. Frank Sanborn, of the Division of Mines, California. [M.A. **5**–145.]

Serpophite. W. N. Lodochnikov, 1933. Problems of Soviet Geology, vol. 2, p. 120 (Серпофит), p. 145 (Serpophite, serpentinophite). Suggested for the compact varieties of serpentine. A combination of the synonyms serpentine and ophite.

Soda-tremolite. H. Berman and E. S. Larsen, 1931. Amer. Min., vol. 16, p. 143. E. S. Larsen and E. A. Goranson, Amer. Min., 1932, vol. 17, pp. 351–353. A variety of tremolite with the formula $Na_2CaMg_5Si_8O_{22}(OH)_2$. [M.A. **5**–216.]

Strontium-anorthite. E. Dittler and H. Lasch, 1931. Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Kl., Abt. I, p. 659 (Strontiumanorthit). Artificially prepared $SrAl_2Si_2O_8$, triclinic and isomorphous with anorthite. [M.A. **5**–102.]

Thoreaulite. H. Buttgenbach, 1933. Ann. Soc. Géol. Belgique, vol. 56, Bull. p. B 327. Tantalate of tin, perhaps $SnO_2.Ta_2O_5$, as brown crystals, perhaps monoclinic, in pegmatite from Katanga. Named after Prof. Jacques Thoreau, of Louvain, Belgium. [M.A. **5**–389.]

Tilleyite. E. S. Larsen and K. C. Dunham, 1933. Amer. Min., vol. 18, p. 469. Silicate and carbonate of calcium, $Ca_2SiO_4.CaCO_3$, monoclinic (?), in a contact metamorphic rock at Crestmore, California. Named after Prof. Cecil Edgar Tilley, of Cambridge. [M.A. **5**–387.]

Topaz-safranite. *See* Safranite.

Tuhualite. P. Marshall, 1932. New Zealand Journ. Sci. Techn., vol. 13, p. 202. A violet-coloured variety of alkali-amphibole with pleochroism colourless, purplish violet, and deep violet, occurring in comendite from Mayor (= Tuhua) Island, Bay of Plenty, New Zealand. Named from the locality. [M.A. **5**–295.]

Uranolepidite. J. Thoreau, 1933. Ann. Soc. Géol. Belgique, Publ. Congo Belge, annex to vol. 55, p. C 3 (uranolépidite), p. C 5 (uranolepidite). Hydrous uranate of copper $CuO.UO_3.2H_2O$, as dark green lamellar masses, monoclinic or triclinic, from Katanga. Identical with Vandenbrandeite (q.v.). Apparently named from uranium and λεπίς, λεπίδος, scale. [M.A. **5**–389.]

Uranothorianite. R. C. Wells, J. G. Fairchild, and C. S. Ross, 1933. Amer. Journ. Sci., ser. 5, vol. 26, p. 47 (footnote). Suggested for a mineral intermediate between uraninite and thorianite, $(U,Th)O_2$.

Vandenbrandeite. A. Schoep, 1932. Ann. Musée Congo Belge, A, Ser. I Minéralogie, Tervueren (Belgique), vol. 1, fasc. 3, p. 22.

Hydrous uranate of copper, $2CuO.2UO_3.5H_2O$, perhaps triclinic, as a dark-green alteration product of uraninite and chalcopyrite; from Katanga. Named after P. Van den Brande, of the Geological Survey of Katanga. *See* Uranolepidite. [M.A. **5**–292.]

Vishnevite. D. S. Belyankin, 1931. Bull. Geol. Prosp. Service U.S.S.R., vol. 50, no. 47, p. 751 (вишневит), p. 752 (vishnevite). The original spelling of Wischnewite (12th List). Named from the locality, Vishnevy Mountains (Вишневые горы), southern Ural. [M.A. **4**–499.]

Wüstite. R. Schenck and T. Dingmann, 1927. Zeits. Anorg. Chem., vol. 166, p. 141 (Wüstit). Ferrous oxide containing excess of oxygen due to the presence of Fe_3O_4 in solid solution. Named after Geheimrat F. Wüst, of Düsseldorf. [M.A. **5**–252, 470.]

Yttro-orthite. A. E. Fersman, 1931. Pegmatites, Leningrad, vol. 1, p. 310 (иттро-ортит). A variety of orthite containing 8% Yt_2O_3, from Kareliya.

SYSTEMATIC CLASSIFICATION OF NEW MINERALS.[1]

Elements.

Rosickyite, γ-S.

Sulphides.

Braggite, (Pt,Pd,Ni)S.
Colusite, (Cu,Fe,Mo,Sn)(S,As,Te).
Kolbeckine, Sn_2S_3.

Haloids.

Jarlite, $NaSr_3Al_3F_{16}$.

Oxides.

Uranothorite, $(U,Th)O_2$.
Galaxite, $MnAl_2O_4$.

Hydroxides.

Portlandite, $Ca(OH)_2$.
Hydrocalumite, $4CaO.Al_2O_3.12H_2O$.

Sulphates.

Letovicite, $H(NH_4)_3(SO_4)_2$.
Amarillite, $NaFe(SO_4)_2.6H_2O$.
Lapparentite, $Al_2O_3.2SO_3.10H_2O$.
Leucoglaucite, $Fe_2O_3.4SO_3.5H_2O$.
Paracoquimbite, $Fe_2(SO_4)_3.9H_2O$.
Glaucocerinite, $Zn_{13}Al_8Cu_7(SO_4)_2O_3.34H_2O$.

Borates.

Ferruccite, $NaBF_4$.
Ginorite, $H_{12}Ca_4B_{14}O_{29}.2H_2O$.
Magnesiosussexite, $2(Mg,Mn)O.B_2O_3.H_2O$.

Phosphates, etc.

Ardealite, $CaHPO_4.CaSO_4.4H_2O$.
Harbortite, $6Al_2O_3.4P_2O_5.17H_2O$.
Minyulite, $KAl_2(OH,F)(PO_4)_2.3\frac{1}{2}H_2O$.
Leucophosphite, $K_2(Fe,Al)_7(OH)_{11}(PO_4)_4.6H_2O$.
Alumo-chalcosiderite.
Legrandite, $Zn_3As_2O_8.3H_2O$.
Brickerite, Arsenate Zn,Ca.
Saleite, $MgO.2UO_3.P_2O_5.8H_2O$.
Hydroromeite, $CaO.Sb_2O_5.3H_2O$.
Corvusite, $V_2O_4.6V_2O_5.xH_2O$.

[1] Only a selection of the names given in the preceding alphabetical list is here included.

TANTALATES.

Thoreaulite, $SnO_2.Ta_2O_5$.

URANATES.

Vandenbrandeite, $CuO.UO_3.2H_2O$.

SILICATES.

Barium-anorthite.
Strontium-anorthite.
Barium-muscovite.
Mangan-muscovite.
Caesium-biotite.
Sanbornite, $BaSi_2O_5$.
Alleghanyite, $5MnO.2SiO_2$.
Johannsenite, $MnCaSi_2O_6$.
Soda-tremolite, $Na_2CaMg_5Si_8O_{22}(OH)_2$.
Tilleyite, $Ca_2SiO_4.CaCO_3$.
Bultfonteinite, $2Ca(OH,F)_2.SiO_2$.
Devitrite, $Na_2O.3CaO.6SiO_2$.
Jäneckeite, $8CaO.Al_2O_3.2SiO_2$.
Madisonite, $2CaO.2MgO.Al_2O_3.3SiO_2$.
Enalite, $(Th,U)O_2.nSiO_2.2H_2O$.
Yttro-orthite, var. of orthite.
Phosphoro-orthite, var. of orthite.
Lusakite,
$H_2(Co,Fe,Mg,Ni)_4(Al,Fe)_{18}Si_8O_{48}$.
Juanite,
$10CaO.4MgO.Al_2O_3.11SiO_2.4H_2O$.
Rilandite, hyd. sil. Cr,Al.
Igalikite, $NaKAl_4Si_4O_{15}.2H_2O$.
Naujakasite, $HNa_3Al_2Si_4O_{13}$.
Cuprosklodowskite,
$CuO.2UO_3.2SiO_2.7H_2O$(?).
Ashcroftine, $NaKCaAl_4Si_5O_{18}.8H_2O$.
Ashtonite,
$2(Ca,Na_2)O.Al_2O_3.9SiO_2.5H_2O$.

HYDROCARBONS.

Balkhashite.
Graebeite.
Kiscellite.

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[See also List of new mineral names (p. 624). Only the main items are here indexed; for fuller details see Index to Mineralogical Abstracts, vol. 5.]

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ERRATA AND ADDENDA

Mineralogical Magazine, vol. 19.

Page.	Line.	
253	5	Orlov (N. A.) *add* [1870–1919]. Biographical notice with portrait and bibliography, by P. N. Chirvinsky, Trav. Mus. Min. Acad. Sci. Leningrad, 1927, vol. 2, pp. 1–36.
262	3	

Mineralogical Magazine, vol. 20.

266	11*	Nicol (W.) *add* born Feb. 18, 1861, died Feb. 24, 1924
446	6*	*For* $Ag_2O.3Fe_2O_3.4SO_3.H_2O$ *read* $Ag_2O.3Fe_2O_3.4SO_3.6H_2O$
469	12	

Mineralogical Magazine, vol. 21.

576	8	*For* orthorhombic *read* monoclinic

Mineralogical Magazine, vol. 22.

284	11*	*For* $2/3 \times (-1)$ *read* $2/3 \times (-3)$
636	3*	*For* $4RtiO_3$ *read* $4RTiO_3$

Mineralogical Magazine, vol. 23.

xv	8*	*For* Willian *read* William
liii	11	*For* Creditors *read* Debtors
17	6*	(f. n. 2) *For* p. 357 *read* p. 257
47	in table	*For* Trolite *read* Troilite
53	13*	*For* $Ca_5Na_7Al_{17}Si_{23}O_{80}$ *read* $Ca_5Na_7Al_{17}Si_{23}O_{80}$
63	9*	*For* Berks. Co. *read* Berks Co.
65	5	*For* Invernell *read* Inverell
66	3*	*For* O. Bøggild *read* O. B. Bøggild
81	15*	*For* Thetford mines *read* Thetford Mines
203	20	*For* Spt_4 *read* SPt_4
357	11*	*For* A. Schuchert *read* C. Schuchert
359	14*	*For* vol. 21 *read* vol. 22
365	col. 2	Nicol, W. *add* (1861–1924)
392	14	*For* 7·66 *read* 7·64
510	4	*For* Orlovo (Орлово) *read* Orlova (Орлова)
547	3*	*For* M.A. 5 *read* M.A. 5–436
563	5*	*For* $\phi = 90°$ *read* $\phi = 0°$

* From bottom of page.